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ABSTRACT

This report, which is the outcome of a joint project of the American Association for the Advancement of Science and the National Association of State Directors of Teacher Education and Certification, considers ways in which science teaching in elementary schools could be improved. It is addressed to scientists, professors of education, college deans, and staff members concerned with teacher education, and describes the skills which teachers will need to teach modern science at the elementary level, the necessary revision of college science courses and the reordering of the professional educational sequence. Nine guidelines are discussed in detail, covering scientific inquiry, attitudes towards science, processes of science, scientific knowledge, continuous learning, instruction, relations with children, relations with other teachers and the administration, and relations with the community. Five standards for teacher education institutions deal with shared responsibility for preservice education, qualified scientific teaching staff, the essentials of the curriculum, individualized instruction, and the provision of adequate facilities and materials. (MBM)

PRESERVICE SCIENCE EDUCATION OF ELEMENTARY SCHOOL TEACHERS

CONTENTS

FOREWORD

Preliminary Report

This report suggests ways in which preservice science education might be improved to bring about more effective science teaching in elementary schools. The purpose of the report is to stimulate discussion and study of preservice education. The AAAS Commission on Science Education hopes that the report will be discussed frequently and critically by groups of scientists, teacher educators, and elementary school teachers and administrators. It is further hoped that these discussions will yield constructive criticisms and suggestions that can be used to revise and strengthen the report in another year.

If the report stimulates discussion, prompts teacher education institutions to give serious attention to updating their preservice programs in science for elementary teachers, and even more importantly, to initiate research and development projects from which better answers to relevant and important questions can be found, the preservice project will have served its purpose.

In its initial planning the Commission requested support for a six-month planning period to be followed by the organization of a cooperative project in four centers in which samples of materials of the kind described in the report would be written and tried. When it was learned that funds would not be available for the developmental work, the Commission decided to go ahead with the planning period with the hope that others would be persuaded to embark on the urgent development and research.

The AAAS Commission on Science Education is well aware of the complexities involved in the preservice education of elementary teachers. Elementary school teachers constitute the largest professional group in the United States. Each year 85,000 elementary teachers are graduated from more than 1,200 institutions of higher education. These teachers are expected to teach language arts, social studies, mathematics, health, fine arts, and physical education in addition to science. Their task is complicated by the fact that recent curriculum projects in mathematics, science, and other areas have redefined what should be taught in elementary schools. While science in elementary schools has been completely changed, most science courses for teachers at the college level have changed little or not at all.[1] Herein lies the pinch of the educational shoe.

Prospective elementary teachers should be prepared to teach new programs in science that are being developed; they should be prepared to continue their study of science after graduation in order to adjust to a changing curriculum. It is often suggested that they should study science in the way that they are

[1] There are exceptions. See for example Physical Science for Non-Science Students (PSNS) developed by a group working at RPI. The materials are published by John Wiley.

expected to teach science to children, but at an adult learning level. Present preservice education programs do not prepare teachers in these ways and improvements are urgently needed.

In 1963, *Guidelines for Science and Mathematics in the Preparation Program of Elementary School Teachers* was prepared by a joint project of AAAS and the National Association of State Directors of Teacher Education and Certification. The NASDTEC-AAAS Guidelines were widely distributed and have brought about improvements in the preservice programs in science and mathematics for elementary teachers. They continue to be of importance. However, the Guidelines appeared before the development of the new elementary science programs and their recommendations are expressed in terms of course titles, which are always subject to misinterpretation. This report provides recommendations for preservice education of elementary teachers, which take into account recent developments in science and in education, and attempts to define what elementary teachers should be able to do.

Two educational innovations of the past year give promise of having a major influence in the improvement of the preservice education of elementary teachers: the new *Standards and Evaluative Criteria for the Accreditation of Teacher Education,* which has been prepared for use by the National Council for Accreditation of Teacher Education, and the Model Programs developed by nine universities under contract with the U.S. Office of Education. These materials have greatly influenced the thinking which led to this report, and they contribute in a significant way to its timeliness. It is reasonable to expect that this report will be useful to NCATE evaluation teams, and will strengthen the science components of Model Projects as they are put into practice.

The recommendations of this report grew out of a series of three conferences in which over sixty leaders in American education participated. They are bold and perhaps idealistic. For this there is no apology—bold action is needed.

The report is the product of the hard work of the participants in the three conferences; their names are listed in the Appendix. Special credit must be extended to the members of the Commission's Committee on Teacher Education: Deborah Partridge Wolfe, Queens College of the City University of New York, Chairman; Hubert N. Alyea, Princeton University; Addison E. Lee, The University of Texas at Austin; Wendell H. Pierce, Education Commission of the States; and William W. Rubey, University of California at Los Angeles and Rice University.

The Preservice Teacher Education Project has been supported by the National Science Foundation.

J. Dudley Herron, Coordinator
Teacher Education Project
AAAS Commission on Science Education

February 1969

This Report

After publication of the Preliminary Report in the spring of 1969, two thousand copies were distributed without charge to persons in all parts of the country who were believed to be interested in the preservice science education of elementary teachers, and their comments were solicited. Four regional conferences were held in October and November 1969, for introduction and discussion of the Preliminary Report. About 100 scientists, science educators, and teachers attended each conference. At the University of Maryland, in Atlanta, in San Francisco, and in Chicago the conferees met for two days during which, in committees on science experiences, experiences with children and schools, research and development, and implementation, they prepared recommendations for revision of the Report. Names of the conference participants are listed in Appendix D. The National Association of State Directors of Teacher Education and Certification, at their annual meeting in June, voted to give their full cooperation in the fall conferences and at least one person from most of the 50 state departments of education participated in one of this second round of conferences.

It has been possible to incorporate most of the conference recommendations in this final draft. This revised report represents the combined work of almost 500 participants from 47 states—almost 100 in the preparation of the Preliminary Report and over 400 in the revision. The preliminary report has been strengthened and the 500 participants are now designated as team members to introduce the report widely, to interpret it, and to assist in implementing it to the end that elementary school children of the future will have better science experiences under the leadership of enthusiastic and well-qualified teachers.

Deborah Partridge Wolfe, Chairman
Addison E. Lee, Member
Teacher Education Committee

John R. Mayor
Arthur H. Livermore
Project Directors

AAAS Commission on Science Education

April 1970

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THE RATIONALE AND ORGANIZATION OF THE REPORT

The success of the new programs in science for high schools pointed up the urgency of, and possibilities for, improving science teaching in elementary schools and colleges. Now new science programs for elementary schools are available and are being introduced into schools. At the same time important changes are taking place in college science teaching and preservice teacher education programs are under constant study. Many innovations are being introduced. The support by the U.S. Office of Education of the development of Model Projects for the preservice education of elementary teachers may result in changes on a wide scale.[2] Furthermore the more realistic and flexible standards of the National Council for Accreditation of Teacher Education not only make change more possible, but actually place a premium on carefully conceived innovations. The time could scarcely be more propitious for a re-constitution of the preparation of elementary teachers to teach science.

This report calls for cooperation among all of those responsible for the many different aspects of preservice teacher education. First, responsible groups must be persuaded that there is need for change, that exciting possibilities for improvement do exist, that there is value in a cooperative effort. Then these groups must become involved and work toward commonly agreed-upon goals. Scientists and teacher educators, the institutions and professional organizations with which they are associated, state departments of education and the schools, their administrators and teachers, and their supporting lay public, must all become involved, and work together toward commonly agreed-upon goals.

New Elementary School Science

New materials have become available within the past eight years which make possible a dramatic revolution in the teaching of science in elementary schools. The standards, guidelines, and recommendations in this report have been prepared for all of those responsible for assisting prospective elementary teachers to acquire the competencies necessary to teach the new science programs. Each of the new science programs is unique in its own way but all possess certain commonalities which should become the principal focus of the teacher preparation program.

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[2] Here and throughout the report, "Model Project" refers to one of the nine models for elementary teacher education developed under contracts with the U.S. Office of Education, Bureau of Research. Models were submitted to the Bureau on October 31, 1968. Further information about the projects can be obtained from Elementary Teacher Education Project, Division of Elementary and Secondary Education Research, Bureau of Research, U.S. Office of Education, 400 Maryland Avenue, S.W., Washington, D.C. 20202.

Some of these are:

1. an emphasis upon the investigative nature of science (inquiry and discovery).
2. a conviction that children need to be actively involved with materials that are conceptually rich for the learning of science.
3. an emphasis upon independent learning with opportunities to explore, "try out," "play with" and in other ways initiate their own learning.
4. an attempt to establish a sequence of instruction to help assure the child's acquisition of skills in the processes of sciences as an important part of their intellectual growth.
5. a valid presentation of science materials so that concepts will not need to be corrected later.

These commonalities are also characteristic of modern mathematics programs for elementary schools.

Broad Concerns

This report begins with the assumption that the new elementary science programs should and will have an increasing influence on the schools. It suggests where we should be going in the preservice education of elementary teachers to prepare them for this anticipated change in elementary science programs. In doing this, the report describes the skills that teachers will need to teach modern science to children, and it contains statements suggesting what to look for as evidence that teachers have the skills that are called for.[3]

Although the primary concern is with science teaching, it is impossible to look at the preparation needed for elementary teachers to teach science without considering other aspects of preservice teacher education. Considerations have ranged from elementary science to liberal education in college, from attitudes to manipulative skills, from performance objectives and individualized instruction to the spirit of inquiry and being human. It is clear that the problem involves more than the revision of college science courses or reordering the professional education sequence.

These broad considerations arise, in part, from a note of general dissatisfaction with the school and society as a whole—it is not only that science is often badly taught; for many youngsters, the entire school experience is frustrating and limits their intellectual development.

These limitations are found in all teaching, not just the teaching of science. Witness the following quote from a recent review by Waetjen:

[3] In the view of many conference participants the teaching of science and mathematics in elementary schools should be integrated or at least correlated. However, almost without exception, science and mathematics are taught in elementary schools as separate subjects. For this reason, and because the Committee on the Undergraduate Program in Mathematics has prepared and widely disscminated recommendations on the preservice mathematics preparation of elementary teachers, preparation in mathematics is not considerd in this report.

"Information which children placed in the (learning) situation was often ignored, overlooked, or not considered by the teacher. More importantly, the kinds of teacher responses which seek expansion and association of ideas, which ask for comparison and inference, and which related to personal experience and opinion occurred rarely." [4]

Those responsible for the preparation of this Report believe that, if the new science materials are taught effectively, some of these limitations of elementary school education will be removed.

To Whom Is the Report Addressed?

The report is addressed to all persons concerned with the improvement of the preservice science education of elementary teachers.

It is addressed to scientists who teach science courses taken by a substantial number of prospective elementary teachers. They must make the important decisions concerning the nature of science experiences for teachers. Are the science experiences that will be most valuable for future elementary teachers the same as those for future scientists, engineers, or even future lawyers? If not, what experiences do teachers need? What must the future elementary teacher know about the problems in environmental science, population studies, genetics and evolution? These are the questions which must be answered. This report outlines many of the skills, attitudes and competencies that the elementary school teacher will need to teach a modern program in science; the design of experiences which will lead to these skills and attitudes is largely left to college scientists.

This report is also addressed to professors of education since they are generally held responsible for the teachers who are prepared by an institution. The professor of science education may find it necessary to include in his science education courses science topics that the prospective science teacher did not have in his science courses or which he has since forgotten. He will assist the student in maintaining a favorable attitude toward science and science teaching and help him develop skills of teaching science to young children. He must constantly be aware of the science experiences with children and schools that the preservice teachers have, and be prepared to supplement the experiences as needed.

College deans and staff members, in addition to scientists and science educators who have special responsibilities for the preservice science education program, should also find the report of value in their consideration of total college programs and the teacher education program of the college.

The standards, guidelines, and recommendations of this Report will be of concern to school administrators, teachers, and state department of education

[4] Walter B. Waetjen, "Recent Analyses of Teaching," *Maryland ASCD Journal*, Vol. 3, No. 1 (Fall, 1968) p. 28.

personnel. The problems that teachers face in the transition from preservice experiences to full responsibility as a teacher in the classroom are well documented.[5] Much of what teachers learn about teaching in the preservice program is learned through experience with children in schools. There are many problems of providing feedback to colleges, planning better clinical experiences, and continuing education during early periods of service which concern school administrators, directors of teacher education and certification, or other staff members of state departments of public instruction as well as college personnel. School administrators will have a larger role in establishing the organization which will make possible a gradual induction into teaching and a continual rebirth of the practicing teacher.

Members of evaluation teams for the National Council for Accreditation of Teacher Education should also find the report useful since it provides standards and guidelines which may be useful in evaluating existing and future preparation programs.

Guidelines

Chapters 2 and 3 are developed around guidelines. These are general statements which may be used by those taking a broad view of the teacher education program. Guidelines must be general but, because they are, they are subject to various interpretations. To help clarify the intent of the Guideline, each is followed by questions that might be asked in evaluating the preservice program.

To further clarify their intent, the guidelines are defined by performance objectives—specifications of what the future teacher should be able to do as a result of his college experiences. Some readers will think that a description of teaching in terms of behavioral specifications implies a mechanical performance by the teacher, that trivial behavior which is easily described is emphasized at the expense of creative performance which eludes definition, that flexibility on the part of the teacher and the pupil is precluded. Such objections suggest possibilities for abuse of objectives which can and should be avoided. No error is made in setting forth clearly defined goals for ourselves or for others; the mistake is in setting trivial goals, in keeping the purpose secret from the student, in the failure to consider his goals. The list of objectives describe competencies that represent minimum requirements for successful science teaching; in some areas the reader will want to add to the list; in all areas students will learn much that is not described by the objectives.

In order to make an objective clear, it is sometimes necessary to provide specific examples of things that a teacher might be asked to do as evidence that he possesses that particular competency. These are examples for which other activities could be substituted.

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[5] See *The Real World of the Beginning Teacher*, Report of the 1965 Conference of the National Commission on Teacher Education and Professional Standards, National Education Association (1966).

Competencies are described at three levels. Level 1 is a general description the competency and is designated by capital letters. Level 2 provides more ecific statements of examples of subordinate skills that contribute to the ility described at Level 1. Level 2 is designated by Arabic numerals. Level 3 ovides specific examples used only when there is some danger that the more neral descriptions may be misleading. Level 3 statements, which are inded as examples only, are set in smaller type to avoid confusion.

Liberal Education

Above all else, the elementary teacher should be a liberally educated person. cause of this, the report would be incomplete without a discussion of the portance of liberal education in the preparation program for elementary chers. However, a careful description of guidelines and performance objeces needed to accomplish the desired end requires careful consideration by erts in fields other than science and education, as well as by those in ence and education. Consequently, no attempt is made to provide guidees for the liberal education of teachers as has been done for experiences science and experiences with children and schools. Chapter 4 is provided the hope that appropriate agencies will provide some needed direction for provement in this important segment of the preservice program for elentary teachers.[6]

Research and Development

Chapter 5 of this report discusses the need for greatly expanded efforts in earch and development and contains descriptions of recommended projects.

Too little is known about the effectiveness of teacher preparation programs. at evidence is there that teachers who have had courses in science are more ctive teachers of science than those who have not? Is there evidence that rses taken as liberal education develop the attitudes and competencies that ascribe to the liberal man? How much responsibility can college students ume for planning their own learning; what can they learn without the proor's lecture as effectively as with? Is it possible to dispense with grades pletely and report progress on the basis of acquired competencies; to give lit for competencies acquired before entering college or for competencies uired through informal learning?

he major thrust of research on teacher education must be toward evaluat- the outcomes of instructional programs in terms of the teacher's performe in the classroom.

ie reader may wish to refer to the Model Teacher Education Program developed by the University ssachusetts under USOE Grant No. OEC-8-089023-3313(010). The appendices on aesthetics, human ons, language arts, and social studies provide numerous examples of performance criteria related liberal education program.

Standards

In Chapter 6 standards to be applied to the teacher education institution and its program of preservice elementary teacher education are stated. These institutional standards are concerned with the staff, programs, and facilities required for the preservice preparation of elementary teachers. The standards are derived from the recommendations in preceding chapters, and are followed by questions that might be asked in judging the quality of the preservice program at a particular institution. These questions are intended for use by those evaluating the programs, including state departments of education and NCATE evaluation teams.

Implementation

The publication of a Report on the preservice science education of elementary teachers will, in itself, have little effect. The report must be distributed, discussed and tried in order to effect change. Participants in the 1969 conferences listed many recommendations, often addressed to particular groups, for implementation of the Report. These are presented in the final chapter.

Definition of Terms

When speaking of teachers at the college level the terms professor or professional staff will be used. The college student is often called just that but more often the term, teacher, is used to indicate his future professional role. To avoid confusion between the student in the elementary school and the student in college, pupil or child is used in referring to the younger learner.

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SCIENCE EXPERIENCES

Our past experiences and professional commitment allow no other view than that science is important; it is important to teachers, it is important to society, it is important to children. The impact of technology is often cited as justification to teach science, and it is. Knowledge of science and technology and their potential effect on society are important in science teaching. But the mode of thought, the way of looking at the world, the way of solving problems, the way of obtaining knowledge that characterize science are far more important contributions of science to society.

It was this kind of contribution of science to society that prompted the Educational Policies Commission of the National Education Association to state:

> The values of which the spirit of science consists should permeate the educative process, serving as objectives of learning in every field, including the humanities and practical studies.[7] . . . To communicate the spirit of science and to develop people's capacity to use its values should therefore be among the principal goals of education in our own and every other country.[8]

In this chapter an attempt is made to outline the competencies in science that elementary school teachers should have. These competencies can and must be acquired in a reasonable amount of time. Time is also needed to study literature, the arts, and social sciences. The focus is on the kinds of science experiences that elementary teachers should have in order to teach as well as to live in contemporary (or ever changing) society.

The teaching functions required of a teacher of elementary school science are likely to vary from region to region and from year to year. For this reason a teacher's preparation through college programs must provide a base which is sufficiently broad and flexible to permit continued study and adaptation to new findings in science and to new teaching methods. It is well to remember that the general approach of a teacher to his teaching functions usually reflects the pattern of instruction which he himself received in college. That is, a teacher who fails to acquire excitement and the spirit of inquiry and relatedness from his own preparation in science is not likely to convey these qualities to his own students.

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[7] *Education and the Spirit of Science*, (Washington, D. C.: Educational Policies Commission of the National Education Association, 1966), p. 22.

[8] Ibid., p. 27.

A recent study of science education for elementary school teachers revealed that many teachers described their programs "with near unanimity as 'irrelevant,' 'uninspiring,' and often 'overwhelming.' " [9] The overwhelming aspect usually develops from forcing too many technical details into the course. The uninspiring and irrelevant aspects arise when college courses fail to reflect and relate to the larger issues of the natural and social world.

For this reason it is important that science programs for teachers should provide, along with key concepts and some details of modern science, clear demonstration of the impact and significance of science and technology to the social, philosophical and historical aspects of the progress of man.

How Should Science Be Taught?

The adage that "we teach as we are taught" is not without foundation. If elementary teachers are to present science as an exciting exploration of the natural world where pupils have ample opportunity to interact with that world, to ask questions of nature as well as of people, and to discover that even young people can find order there, teachers, too, must have such opportunities. What is done in college science courses will materially affect the way that elementary teachers teach science.

The following sketch of the science teacher, adapted from a conference working paper,[10] was written as a description of the attitude an elementary teacher should have toward science and how it should be taught; it is equally valid as a description of the way science should be taught to the teacher.

> A liberally educated teacher understands that his power derives from the way that content is used as well as from the particular content he has mastered.
>
> The methodology adopted by the teacher makes learning possible for different students. The methods themselves are characterized by openness and can be the subject of discussion and analysis by students. The teacher's aims and his methods should be tempered by the aims and abilities of his students.
>
> Some of the practices that distinguish the effective teacher in the classroom are as follows:
>
> —He acts as a guide to learning rather than simply as a dispenser of information.
>
> —He values the asking of questions as well as the giving of answers.
>
> —He understands that learning is cumulative and does not impose closure prematurely.
>
> —He recognizes the importance of speculative thinking and does not insist that evidence be interpreted in conformity with cultural tradition.

[9] Mathew H. Bruce and Albert F. Eiss, *Science Education for Elementary Teachers*, Final Report USOE Project No. 7-C-016 (October 1968), p. 11.

[10] Adapted from a working paper prepared by Randolph Brown, Elementary Science Study.

—He recognizes that there are several alternative approaches to solving problems and provides opportunities for students to utilize means that they find appropriate.

The desired mode of teaching is illustrated by the following approach to the idea of classification. The teacher begins by providing students with experiences which deal with sets of things and he affords them such experiences over a period of time, recognizing that classification is a skill or a method of gaining control of potentially unmanageable objects or ideas; it is not an end in itself. Counting money, sorting the pieces of mixed games, sorting mixed decks of cards, and arranging the food in a cupboard are examples of activities in which classifying is a means to an end.

In the case of teaching biological classification the teacher will recognize that familiarity with living things is a prerequisite to any need to know about their classification. Students will thus be encouraged to culture, cultivate, and maintain a variety of living things. Many questions can be explored that are relevant to these activities. How long does it take for beans to sprout? for corn or wheat? How early can you tell if a sprout is that of a bean or a corn plant? Similar questions might be asked about molds, fish, and insects. Opportunities to do quantitative measurements, develop concepts of mass, nutrition, and growth are also provided in these explorations. Eventually, the phylogenetic classification that biologists favor will also be seen as useful and hopefully for reasons other than passing tests.

There is a teaching style implied in the above account that is important. Guideline I is related to this teaching style by college professors and to the probable effect of the teaching style on students. This guideline and those that follow describe what the teacher should be able to do. How the college science experiences are designed to accomplish these ends may vary, but there is a minimum set of terminal behaviors[11] which every teacher should possess. Where possible, the statements imply the level of competency to be expected as well as the range and are written in such a way that they suggest how to determine whether the objective has been met. Each institution should develop its own list, more complete than the sample provided here. It should be emphasized that **statements in small type are only examples.** The specific activities described in these statements may not be in the curriculum at all; hundreds of similar activities could be substituted.

[11] There are many points in the course of teacher preparation that could be considered terminal. In this report, terminal behaviors represent those behaviors that the teacher must exhibit before being recommended for certification.

SCIENTIFIC INQUIRY

Guideline I. Science for elementary teachers should be taught in the same style of open inquiry that is encouraged in elementary science programs. The student's science experiences should develop his ability to actively investigate natural phenomena and should result in his enthusiasm for and confidence in teaching science through inquiry to children.

- What evidence is provided that the science experiences provided by the institution encourage open inquiry as a style of learning about the natural world?[12]
- What evidence is provided that teachers are able to teach in a style that encourages inquiry on the part of pupils?

Objectives:

A. **Ability to investigate.** The teacher will demonstrate his ability to carry out an investigation when presented data or a question about a natural phenomena.

Given data about the melting of ice when salt is added to it, construct and carry out an investigation to measure the temperature of mixtures of different amounts of ice and salt.

Given a question about the relationship of the color of the ambient light and the growth rate of plants, construct and carry out an investigation to measure the growth rate of plants in light of different colors.

B. **Science as inquiry.** The teacher will demonstrate his enthusiasm for teaching science as inquiry to children by emphasizing investigation over memorization of facts.

When asked by a child why ice floats on water suggests an investigation through which the child might find an answer to the question.

C. **Teaching science as inquiry.** The teacher will demonstrate confidence in his ability to teach science as inquiry by selecting the inquiry approach rather than the show and tell approach.

When asked to teach some children the law of the pendulums, gives the children string, steel washers, a stop watch, and meter sticks and suggests that they investigate the relationship between the length of the pendulum and the number of swings per minute.

ATTITUDES TOWARD SCIENCE

Guideline II. Science experiences of elementary teachers should develop in teachers an appreciation for the historical, philosophical, and current significance of science to society, and positive attitudes about science which result in a more objective approach to everyday problems, in improved teaching of science in their classroom as well as in increased interest in science-related activities.

- What attitudes toward science does the institution claim it is developing?

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[12] The questions following each of the guidelines may be useful in evaluating preservice science programs.

- What evidence is provided that these attitudes are held by teachers at the end of the instructional program?
- What evidence is provided that these attitudes persist after teachers have been in service for one or more years?
- What evidence is provided that realistic attitudes are being developed toward the possible solution of major problems such as population growth and environmental pollution?

Some Objectives[13]

A. **Demand for data.** The teacher will demonstrate confidence in scientific measurements, empirical data and accepted principles, and to question unsupported pronouncements. For example:

Reject legislative attempts to set the value of $g = 2.00$ m/sec^2 or $\pi = 3.00$ as nonsense since these constants are empirically derived quantities.

When told that a proposed chemical plant will not disturb the ecology of the region, ask for supporting data and a clarification of assumptions on which the projection is based.

B. **Nature of concepts and theories.** The teacher will recognize that the established concepts and theories of science are valid only insofar as they are consistent with the observed phenomena of nature and that they must be modified if this is necessary to accommodate new findings.

1. Given experimental results in which the mass of the identifiable products is not the same as the mass of known reactants, search for some explanation for the apparent disagreement with the law of mass conservation.

   When presented data that show that the mass of a grown plant and the soil that it is planted in is greater than the mass of the original soil, seed, and water added, suggest other materials that may have contributed to plant growth.

C. **Interest in science.** The teacher will demonstrate his interest in science by activities such as reading and conducting experiments.

1. Read science-related articles and books which are not required as part of a course.
2. Plan and conduct experiments on his own volition or manipulate science equipment provided by the professor when he is invited (but not required) to do so.

D. **Encouraging science activities in pupils.** The teacher will encourage

[13] Writing objectives to describe attitudes is a hazardous undertaking. We cannot measure attitudes
in the sense that we measure length, time, or even knowledge. We can only look for a kind of behavior
from which we are willing to infer that the attitude in question does exist. But this is not entirely
satisfactory. The observed behavior may depend on the person's attitude but it is likely to depend on
knowledge, skills and the circumstances surrounding the performance as well (see A, B, C, in this sec-
tion). A further problem that arises with writing objectives to describe behaviors which evidence atti-
tudes, is that the behavior mentioned becomes an end in itself, and may therefore be produced by a
desire for a high grade, as well as by the desired attitude. The teacher's performance in the class-
room after his preservice education has been completed will provide the true test of whether these
objectives have been attained.
In writing the objectives in this section an attempt has been made to use such terms as "demon-
strate confidence," "demonstrate an interest in science" and "suggest investigations" to denote some
action on the part of the teacher from which one may infer that the desired attitude is present. For
a more elaborate discussion of attitudes and problems of measuring them, the reader is referred to:
Mager, Robert F., *Developing Attitude Toward Learning* (Palo Alto: Fearon Publisher, Inc., 1968).

pupils to show curiosity and inventiveness in science by helping pupils design experiments that will answer their questions.

When asked, "Will a flashlight work if the batteries are turned upside down?" suggest that the pupil try to find the answer.

Suggest investigations that pupils might conduct in their study of the behavior of mealworms without requiring that the suggestions be carried out.

E. **Relevance of science.** The teacher will state how the lives of some members of a community have been affected by science and technology resulting from science.

1. Suggest investigations of the development and use of forms of energy such as electricity and nuclear energy.
2. Plan and conduct a visit to an installation which processes the wastes of society.
3. Suggest investigations that will illustrate the effects of waste products from engines upon plant and animal life.

THE PROCESSES OF SCIENCE

Guideline III. The science experiences for elementary teachers should develop competence in inquiry skills or processes of scientific inquiry.

- What processes has the institution identified as important characteristics of scientific inquiry?
- What evidence is provided that teachers make use of process skills in their study of science?
- What evidence is provided that teachers continue to use these skills in their own teaching?
- What is done to develop an awareness of instances in which commonly accepted scientific laws break down?

A. **Observation and inference.** The teachers will distinguish observations and evidence from inferences and conclusions, and will demonstrate his ability to make reasonable inferences when presented with empirical data. For example:

1. Given data concerning the fossil records of a region, voluntarily construct inferences concerning its geologic history.
2. Construct testable inferences to explain the unusual growth rate of a plant without being asked to do so.

B. **Variables.** Through the observation of a phenomenon the teacher will be able to state a problem to be investigated, identify the variables which affect the results of the investigation and how and why they are or are not controlled.

C. **Definitions.** The teacher will distinguish between operational and conceptual definitions.

D. **Measurement.** The teacher will demonstrate the measurement of variables such as length, mass, force, time, temperature, and volume in standard and arbitrary units and estimate the error of measurement. The following areas should be included:

Determination of Magnitudes
Finding rate of change, given measurements that change with time
Probability and uncertainty

E. **Classification.** The teacher will construct a classification scheme for a set of objects, given objects which differ in more than one way. Use a given classification scheme to identify living and nonliving materials. Objects from the biological, physical and earth sciences should be used for classification.

F. **Organization of data.** The teacher will collect and organize data and describe the rationale for the organization.

1. Present data obtained in a science experiment by describing, drawing a diagram, graphing, or tabulating.

   Construct a graph of data collected which shows the volume of a confined gas as a function of temperature.

G. **Constructing hypotheses and generalizations.** The teacher will construct a hypothesis, or generalization based on data or a question.

1. Construct a hypothesis to explain an unfamiliar phenomenon demonstrated by the professor or shown in a film clip.

H. **Testing hypotheses.** The teacher will construct an experimental test of a hypothesis. inference, generalization, or question.

1. Test the validity of the hypothesis made to explain an unfamiliar phenomenon by performing an appropriate experiment.

I. **Modifying hypotheses and generalizations.** The teacher will accept, reject, or modify hypotheses, and generalizations based on new data and describe the basis of the decision.

1. Modify a generalization and justify the modification on the basis of empirical data or of assumptions of a theory.

   Modify a hypothesis concerning the volume of a confined gas as a function of temperature by restricting the range of temperatures over which the generalization is expected to hold.

J. **Verifications.** The teacher will demonstrate a recognition of the need for additional information in some situation by searching out the information or designing an experiment.

1. When confronted with alternative interpretations of data which are obtained, check the results by returning to the laboratory or referring to a reference work to obtain additional data.

K. **Communication.** The teacher will describe an experiment orally or in writing with sufficient clarity that another person could replicate the experiment.

L. **Model Building.** The teacher will devise and use a mathematical or physical model of the system being studied which contains the essential variables and their relationship.

SCIENTIFIC KNOWLEDGE

The elementary teacher should possess a background of science information. It is unreasonable and unnecessary to expect elementary teachers to learn all of their science while they are teaching it to children. Yet elementary teachers frequently complain that this is precisely what they are required to do because they see no relationship between the content and mode of instruction of their college courses and science they are expected to teach. Efforts should be made to relate the science topics that are taught to teachers to the science topics that are taught to children.[14] The college professor must constantly remind himself that the teachers will not become research scientists. They may benefit more from qualitative and semi-quantitative treatments which are correct but incomplete than from rigorous arguments which depend on mathematical sophistication or logical subtleties that they unprepared to follow.

To accomplish the objective of providing appropriate science education for teachers, professors of education and professors of science must cooperate in planning and implementing these science programs.

Guideline IV. The content of college science experiences for elementary teachers should be selected so that the topics studied by teachers provide, as a minimum, an adequate background for the topics taught in elementary schools.

- What evidence is there that the topics treated in the college science experiences for teachers prepare the teacher to deal effectively with science in elementary schools?
- What mechanism is used to assure that the college experiences are periodically revised to reflect changes in science at the elementary school level?
- What mechanisms of communication are used to ensure that the college periodically reexamines and revises its programs to reflect changes at other educational levels.
- What evidence is there that the content is structured to require the teacher to utilize the fundamental concepts of science as a unifying rationale for all natural phenomena?

Suggested Topics

A. **Composition characteristics and structure of matter.**[15] The teacher will describe observations of living and nonliving objects in terms of their physical, chemical, and biological composition, characteristics, and structure. He will demonstrate the use of the particle nature of matter—molecules, atoms,

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[14] This does not mean that the content of the college course should be dictated by elementary programs or that the level of treatment need be the same as that in elementary science. It does mean that care should be taken to consider the science that elementary teachers will be teaching, that those concepts that they will be expected to teach will be dealt with in college courses, that attempts will be made to point out the relationship between what teachers study and what they will teach, that sophisticated treatments of theoretical topics will be delayed until the teachers have mastered the simpler underlying ideas.

[15] See Appendix C for a further development of this topic.

atomic nuclei—and kinetic theory to explain the observations he describes. The following areas should be included:

Physical properties such as density, viscosity, pressure, solubility, elasticity, surface tension
Physical changes in physical, biological and geological systems
Morphology of living things
Atomic theory
Kinetic theory

B. **Interactions of matter.** The teacher will describe observed interactions of living and nonliving matter using concepts such as forces, electrical charge, magnetic fields, biological tropisms, and food webs. He will construct hypotheses and tests of hypotheses concerning the observed interactions.

C. **Conversion and conservation of energy.** The teacher will demonstrate the conversion of energy from one to another, will measure the amounts of energy transformed, and will search for sources of energy loss when observations appear to contradict the generalization that energy is conserved. The following areas should be included:

Transfer of energy
Transformation of energy in living and nonliving systems
Conservation of energy
Energy carried by waves

D. **Growth and reproduction.** The teacher will describe the processes of growth and reproduction in plants and animals including man.

E. **Evolution and genetics.** The teacher will construct inferences about the long range effects of selective mating and genetic mutation on plant and animal communities and sometimes including human communities and societies. Topics should include the following.

Variation
Adaptation
Mutation
Principles of Evolution and Genetics
Structure and Function

F. **Ecology.** The teacher will describe the interactions which exist among living organisms in ecosystems.

G. **Human perception, learning, and behavior.** The teacher will describe the neurological basis of perception, learning, and behavior.

H. **Conceptual structure and world view.** The teacher will describe the nature of the earth, the universe and the biotic world and construct physical and mental models that can be used to explain natural phenomena they encounter. The following areas should be considered:

Observational astronomy
Historical geology

I. **The development of scientific ideas.** The teacher will describe the relationship of the progress of science to the development of modern thought.

The unknowns of science as well as the knowns

The failures as well as the successes of scientific endeavors

The relationships of scientific disciplines to each other

J. **Social implications of science.** The teacher will state evidence of changes in society and culture that have resulted from the products of scientific work, and of the influence of social conditions on scientific activities.

Relationship of science to the progress of civilization

The cybernetics aspects of scientific thought and social phenomena

CONTINUOUS LEARNING

Science experiences should develop in teachers habits of continually seeking new information, of testing old concepts against new ideas, and of modifying their instructural procedures if new information about science or learning suggest modification. The way in which science is taught can have a significant effect on developing these habits in teachers. Developing the habit of continuous learning in teachers is probably the single most important outcome of preservice education. Without the habit, a teacher will quickly become obsolete and ineffective; with it, he can continually improve his teaching skill and effectiveness. Without the habit he will have difficulty coping with future changes in elementary science education; with it he will welcome the challenge of change.

Guideline V. Science experiences should be selected so as to develop a capacity and disposition for continuous learning which the teacher should demonstrate by engaging in science activities which will provide new information and experiences capable of affecting existing attitudes, ideas, and teaching.

- What experiences are provided through which the teacher can develop a capacity and disposition for continuous learning?
- What evidence is there that new information and experiences affect the teacher's attitudes, ideas, and teaching?
- What encouragement and opportunity are given to teachers exhibiting these behaviors?

Objectives

A. **Capacity and disposition for continuous learning.** The teacher will demonstrate his capacity and disposition for continuous learning by habitually engaging in activities which will provide new information capable of affecting existing attitudes and ideas.

1. Identify and describe view points on contemporary scientific issues and on the learning process as presented in current literature, or through personal contacts.

   Describe arguments for and against the use of an insecticide and suggest possible safeguards, after reading an article about potential damage to wildlife from uncontrolled use of the insecticide.

After reading about some recent research on the learning process, infer the implications of that research for elementary school programs.

2. Demonstrate the ability to obtain relevant information on scientific and educational issues.

   Locate historical accounts of experiments pertaining to Mendel's law.
   Identify sources of analyses of educational philosophies.

3. Identify possible interrelationships between events in different fields of knowledge.

   After reading an article on physiological changes brought on by malnutrition, consider whether such changes might affect the learning behavior of a child from a ghetto.

   Describe some of the interrelationships between scientific and political developments.

4. Identify weaknesses in his educational background and correct them accordingly.

   After reading an article on the use of performance objectives, develop skill in writing them by reading books such as *Preparing Instructional Objectives* by Mager and discussing his work with informed colleagues.

   After hearing that irregularities in the gravitational field of the moon have introduced an unexpected hazard in landing men on the moon, demonstrate his ability to use current popular or semi-popular scientific periodicals to obtain information about the cause of the gravitational irregularities.

Specialist Science Teachers

In the above list of competencies no distinction is made between the person who will teach in a self-contained classroom and the special science teacher. The question of whether science should be taught by a special teacher or the teacher responsible for all other subjects was discussed at all seven conferences and good arguments were heard for both sides.

The nature of the science programs for pupils will determine the competencies their teachers should possess. Thus, it is the nature of the science that is to be taught in elementary schools rather than the instructional organization that dictates the requirements of the preservice program. The important question is what any teacher who teaches science should be qualified to do. At the same time the desirability of having some teachers who can do more, is fully recognized.

The science specialist may be defined as a person who assumes a leadership role in the development of curriculum materials and the inservice education of other teachers. The specialized part of the education of this kind of science specialist is commonly postservice rather than preservice, and a description of the unique set of behaviors required is beyond the scope of this report.

Are The Competencies Reasonable?

It is anticipated that a number of prospective teachers possess many of the competencies that are described in this chapter at the time they enter college. Certainly much of the content implied in the objectives is standard fare in modern high school courses. It cannot be overemphasized that the teacher is expected to exhibit certain competencies, not to amass a certain number of credits in college science. If a teacher can measure mass, length, temperature, volume, and time when he begins his first college science course, activities designed to teach him to do so are a waste of time. If he has demonstrated his ability to construct a classification scheme for plants during college experiences in the biological sciences, it is unlikely that extensive experience will be required before he can do the same thing with rocks and minerals. There is every reason to believe that the proper coordination and individualization of science instruction can eliminate needless repetition and conserve considerable time needed for other activities.

3

CHILDREN, TEACHING, AND SCHOOLS

Everyone would agree that to teach science a teacher must know something about science; he must understand the attitudes, the principles, and the procedures from which the scientist operates; and he must be able to operate within this same framework, though at a different level of sophistication. Even if the science experiences produce the attitudes, the knowledge, and the process skills described in Chapter 2, there is no assurance that the teacher will be able to communicate science to children. It is one thing to believe in conservation of substance; it is another to select activities which will convince children that such a generalization is plausible. It is one thing to be able to observe, classify, define operationally, or to make and test a hypothesis; it is another to lead children to do the same.

This chapter provides some description of the experiences with children and schools that may facilitate development of skills required to teach science to children. The USOE Model Projects have been closely examined and an effort has been made to make these recommendations compatible with the Models. Reference in this chapter is purposely made to the teaching of science, although most of the behaviors that are described may be applicable to other areas.

There may be some argument that the behaviors regarding human relations that are described in this chapter should be used as criteria for screening students seeking entrance into teacher education, rather than as abilities to be developed as a part of the preservice program. However they are viewed, they are behaviors crucial to effective science teaching.

A Suggested Program

Much of what prospective teachers must learn about teaching will develop out of carefully planned experiences with children and schools. Early experiences of the teacher with children in schools should occur during the first or second undergraduate year when the prospective teacher is enrolled in science and other courses which provide background for his future career. These early experiences may involve in-class observations and part-time work as a teaching aide but many of them could be simulation experiences presented by film or video-tape and designed to focus attention on particular science teaching strategies. Provision should be made for the teacher to suggest possible strategies that he might use at critical points in the lesson.

The observations and stimulated classroom episodes should be followed by opportunities for students to teach science lessons; first with one child in a tutorial, later to a small group in a microteaching format, and finally in a self-contained classroom or as a member of an instructional team. Many opportunities should be provided for the student and professional staff to evaluate the student's teaching performance. Only when the student shows proficiency in teaching science in a small group teaching situation should he proceed to work with larger groups with all of the complex interactions which characterize the science classroom.

Ideally, the preservice experiences would culminate in an internship program or assignment to a portal school.[16] By this time the teacher would be largely self-directed. He would be paid for his work in the portal school and would teach without constant supervision. However, experienced teachers, psychologists, consultants, supervisors, test specialists, and others would be available for consultation should the teacher be faced with a problem he is not equipped to handle. After one or two years of service the teacher candidate would be recommended for certification as a fully responsible teacher.

Inherent in this model is the assumption that universities, teacher education institutions, and schools can and will develop a coalition for the preparation of teachers. There are compelling reasons to do so. There should be a consortium of schools and institutions engaged in the preparation of teachers, so that there can be close cooperation in planning and carrying out teacher education programs. Regularly scheduled conferences of representatives of the colleges and the schools are recommended. Visits to schools by college staff members can be beneficial both to college faculty and to teachers. We can no longer afford to send teachers into schools with new ideas they are never allowed to implement and to be faced with demands which they are unprepared to meet. The establishment of adequate relationships between colleges and schools is one of the institutional standards set forth in Chapter 6.

Cooperative institution and school activities provide for interactions among faculty and administration from both levels. A consortium or cooperating group would of course be concerned with the entire teacher education program. In addition, attention should be given to special areas such as science teaching. Scientists and science educators from the institution could become more familiar with problems and helpful strategies in elementary school science through teaching in the schools. Elementary school teachers could be consulted in planning college science programs in order that these more realistically reflect the needs of teachers.

The behaviors of science teachers outlined below are presented as a sample. They represent the skills and competencies that the experience of conference participants believe to be characteristic of successful elementary teachers. Re-

[16] The term "portal school" is borrowed from *A Model for the Preparation of Elementary School Teachers* developed by Florida State University under USOE Grant No. Vogel OECO-8-089021-3308(010). The term refers to schools which have cooperative agreements with universities for the preparation of elementary teachers and have "principals and other status leaders . . . favorably inclined toward innovation . . . use some of the 'new' curricula . . . in mathematics, science, or social studies . . . will be employing organizational arrangements that include utilization of para-professionals and teacher aides . . . [and] will make considerable use of new teaching media." P. 118.

ports from the USOE Model Projects were especially helpful in the development of these guidelines.

INSTRUCTION

Guideline VI. ***The institution, working cooperatively with schools, should provide experiences with children and schools so designed that the teacher develops the skills required for effective instruction in the science program.***

- What skills has the institution identified as required for effective instruction in science?
- What systematic method of recording or describing teaching performance is used to enable prospective teachers and staff members to analyze the extent to which instructional skills are demonstrated?
- What evidence is provided that plans for the experiences with children and schools have been developed cooperatively between the institution and the schools involved?
- What evidence is shown that the schools and colleges working together have provided experience in working with modern science programs?

Objectives [17]

A. **Objectives of instruction.** Upon being asked the purpose of an activity in the classroom, the teacher will be able to describe the objectives of the science instruction in precise terms and support his choice of objectives.

1. Identify objectives appropriate to developing (a) intellectual or process skills, and (b) concepts in science.
2. Identify examples of objectives which relate to systematic thinking.

   From a list of science objectives, identify those which require the pupil to use application, analysis, or synthesis as defined by Bloom.[18]

3. Identify examples of objectives which relate to creative thinking.

   From a list of science objectives, identify those which require the child to formulate a concept on his own, or to plan an investigation without assistance.

4. Select objectives for his class in terms of the unique needs and characteristics of his group and individual children in the group.
5. Identify or construct instructional modules or units which contribute to specific goals of science teaching.

   Given the objective, "The pupil will be able to distinguish facts from conjectures or inferences in a variety of situations," select or construct instructional materials which contribute to the accomplishment of that objective.

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[17] Other excellent lists of behavioral specifications may be found in reports of the USOE Model Projects; see *A Competency Based, Field Centered, Systems Approach to Elementary Teacher Education,* Northwest Regional Educational Laboratory, USOE Contract No. OEC-8-089022-3318(010). Vol. 1, pp. 54-62; Vol. 2, Appendix F and Appendix H.

[18] Benjamin S. Bloom (ed.). *Taxonomy of Educational Objectives: Cognitive Domain.* New York: David McKay Co. (1956).

B. **The learning environment.** The teacher will demonstrate the organization and maintenance during instruction of a classroom environment which fosters inquiry.

1. Schedule class time to allow for both group and individual activities designed to accomplish specific objectives.
2. Demonstrate the introduction of a science activity in such a way that pupils are motivated to conduct investigations.
3. Create an atmosphere in which children participate freely in planning, carrying out, and interpreting results of investigations.
4. Use questions to assist children in conducting an investigation without telling them what to do or giving away the expected results.
5. Arrange instructional resources in the classroom to maximize pupil interaction with the materials.

    Collect materials locally to be used in an exercise on classification.

6. Locate and use instructional resources available in the school and community.

    Locate resource books for children to read on the care of animals in the classroom.

7. List sources of science materials.

    Identify at least three sources of chemicals that might be used in elementary classrooms.

C. **Instructional strategies.** The teacher will demonstrate the ability to select and use a variety of learning strategies appropriate to various learning requirements.

1. Given an objective for science instruction, select materials, media, and activities in terms of the needs and characteristics of his group and the individual children in the group.
2. Identify instructional materials and learning activities for different learner interests and capabilities.
3. Encourage and enable the children to plan, carry out, and interpret the results of class or individual investigations.
4. Modify planned strategies as a result of unexpected pupil performance.
5. State the basis for his selection of learning strategies.
6. Demonstrate the ability to use effectively both the hardware and software of instructional technology and the willingness to learn how to use new technology.

D. **Constructing a sequence of learning activities.** The teacher will construct a sequence of learning activities on the basis of long-range objectives and knowledge of prior pupil performance.

1. Select, or construct, alternative learning activities when pupils demonstrate that they have achieved the objective of a science activity prior to its being carried out.

2. Select, or construct, alternative science activities when the prior instruction has been unsuccessful.
3. Construct appropriate and significant science activities for pupils whose lack of achievement indicates that they are not ready to continue with the rest of the class.
4. Identify a learning sequence appropriate to the development of skills and attitudes which may emerge over a long (at least two-month) time interval.
5. Identify the experiences, information, and conceptual knowledge prerequisite to specific science principles, laws, and theories.
6. Relate curriculum and methodology to the development of logical processes in children.

E. **Evaluation of pupil progress.** The teacher will demonstrate the use of various individual and group assessment devices to determine whether specified objectives have been met and other desirable outcomes have been achieved.

1. Select, or construct, and administer science assessment items which require pupils to use concepts in new contexts and inquiry skills in new problem situations.
2. Distinguish between acceptable and unacceptable responses to assessment items in science.
3. Use various assessment devices to determine the degree to which pupils possess necessary prerequisites for a learning task in science.
4. Use the results of evaluation in planning subsequent science learning activities.
5. Describe the results of evaluation to pupils and parents so that it is clear whether the pupil is or is not making reasonable progress in science.

RELATIONS WITH CHILDREN

Guideline VII. The institution should insure that the teacher possesses skills required for effective human relations with children in the classroom by carefully and continually screening candidates for the teacher education program and providing experiences in which students develop the desired behaviors.

- What skills in relations with children must the teacher demonstrate in order to be recommended for certification?
- What screening procedures and learning experiences are provided to assure that teachers possess the desired behaviors?

Objectives

A. **Recognition of the importance of individual children.** The teacher will demonstrate the ability to accept pupils as individuals by responding to manifestations of individual differences in a controlled manner.

1. Demonstrate ability to guide pupils who are creative, who ask probing questions and who present challenging ideas in science.
2. Exhibit competence in working with the pupil who has poor manipulative skills in handling equipment or who is slow in acquiring process skills by providing experiences in which the child can succeed, by giving words of encouragement, and by deferring required performance when the child shows evidence of extreme frustration.
3. Demonstrate empathy, appreciation, and ability to work with children of divergent backgrounds and interests that affect their motivation for participation in science experiences.
4. Demonstrate empathy toward pupils with personal problems by modifying requirements for the individual and obtaining professional outside help where necessary.
5. Encourage the child to express himself in those ways which are most familiar and understandable to the child, in speech patterns other than the conventional, allowing the child to express himself in a variety of ways, such as through pictures, demonstrations, models, and role playing activities.
6. Demonstrate faith in the ability of each child to make a valid contribution to the solution of the group's problems by listening to and accepting the ideas and suggestions of each pupil.
7. Demonstrate the ability to assist pupils in becoming more sensitive to the needs and capacities of other pupils, by encouraging them to ask questions of each other, to respond to the questions posed by other pupils, and to plan together to solve problems.

B. **Showing confidence and flexibility in relations with children.** The teacher will demonstrate confidence and flexibility by making reasonable alterations in teaching procedures in the face of unexpected events.

1. Demonstrate self-control over attitudes, feelings, and emotional reactions as shown by voice quality or facial and body gestures when responding to children, and ability to listen to children with interest and involvement.
2. Demonstrate confidence in his knowledge of science by failure to display frustration or embarrassment in the face of questions that he cannot answer.
3. Demonstrate the ability to turn ambiguity and unpredictable events which occur during the course of a science investigation into learning experiences.
4. Foster an atmosphere in which individual children and small groups can work independently in science.
5. Demonstrate the ability to guide children in making plans for a science activity without making the decisions for them.

6. Demonstrate the ability to assist pupils in carrying out and in interpreting the results without telling them what must be done or what conclusions are reasonable.

RELATIONS WITH OTHER TEACHERS AND THE ADMINISTRATION

In his preservice years the teacher must learn about relationships among members of the school staff. He must be able to work effectively with parents, administrators, and other teachers. The development of these abilities is the concern of Guideline VII. Guidelines of the USOE Model Projects also provide needed guidance on the development of these important competencies.

When he assumes a teaching position the teacher may be asked to participate in any one of a variety of organizational patterns for instruction. He may be a self-contained classroom teacher with much or little assistance from helping teachers, principals, or other supervisory or administrative personnel. He may work as a member of an instructional team, a practice that can be effectively used in teaching science. It will be important that he understand the role of the teacher, assistant teacher, teacher aide, educational clerk, media aide, science consultant and other members of the instructional staff or team. He should be able to work effectively with all of these people in planning and executing science instruction.

In this section and the one which follows, Relations with the Community, the competencies identified apply to all teachers and, in general, are not unique for teachers of science. Nevertheless the importance now placed on science, and the concerns about science felt by many, make these abilities of special importance for the science teacher. The authors of this Report and the conference participants are convinced that these competencies should not be overlooked even when attention is focused on science education.

Guideline VIII. The institution should provide experiences which will enable the teacher to develop cooperative working relationships with other teachers and administrators of the school faculty which he joins and to work effectively in a variety of organizational patterns for science instruction.

- What evidence is there of the kind of relationships that the student has established with other school personnel?
- What kinds of experiences are planned to assist the teacher in developing a sensitivity to the needs, interests, and responsibilities of others?
- What experiences are provided in which the teacher functions in several different modes of science instruction?
- What evidence shows that the experiences provided are effective in developing the desired competencies?

A. **Relations with other teachers.** The teacher will demonstrate his sensitivity toward, and respect for, other teachers as persons and as professional colleagues. He will show appreciation for the contributions of other teachers to the total school program, to the science program, to each other, and to him.

1. Demonstrate respect for the opinions of others. Listen to what others have to say about science and science instruction. Seek rational bases for the views of others when they are different from his own.
2. Seek assistance and counsel from more experienced colleagues, including secondary school science teachers, and take appropriate action.
3. Demonstrate the ability to tolerate differences in values, language, and behavior patterns of other teachers.
4. Demonstrate self-control by not showing frustration or anger in the face of probing questions or ideas which challenge his own position.
5. Exhibit courage and confidence in his ability by taking considered action that may be criticized by others. Agree or disagree with policy set by teacher groups and give reasons for his position.
6. Demonstrate the ability to show appreciation for the achievement of his colleagues, and recognition given this achievement.

B. **Relations with the administration.** The teacher will demonstrate the same sensitivity toward, and respect for, the administration of the school, as he shows for his fellow teachers. The behaviors described under A are applicable to administrators as well as teachers, and there are, in addition, some special relationships which he needs to be prepared to carry out with emotional maturity.

1. Demonstrate respect for the authority that the school system has placed in the office of the administrator.
2. Where differences of opinion arise concerning the science program, present evidence in support of the teacher's point of view.

C. **Relations as a member of an instructional team.** The teacher will demonstrate the ability to contribute to cooperative team planning of science instruction, and to work in a team without alienating others or becoming alienated.

1. Demonstrate the ability to cooperate in team planning by negotiating and accepting compromises while developing or prescribing science activities to be carried out by the cooperating team.
2. Modify teaching behaviors consistent with cooperative teaching.
3. Direct a teacher aide in a task supporting the team effort without alienating the aide.
4. Modify the directions given to supporting personnel on the basis of their suggestions.
5. Accept directions or help from another member of an instructional team in science without demonstrating personal disaffection.

RELATIONS WITH THE COMMUNITY

In his preservice years the teacher must learn about schools and their relationship to the community. He must be able to work effectively with parents.

He will be called upon to meet with community groups interested in the schools, and he should be prepared to listen to their ideas and present his own in a straightforward and confident manner. The importance now placed on science by many in the community will provide the science teacher special opportunities to discuss his school's science program. As a part of his preparation to work cooperatively with the community, he must learn about the school as a part of the community and the school as an essential part of a democratic society.

Guideline IX. Experiences in schools and in a community should be provided to develop a sensitivity toward, and an appreciation for, the school as a part of the community and as a democratic institution, and for individuals in the community.

- What kinds of experiences are planned to assist in developing a sensitivity for and an appreciation of the values of the community in which he teaches?
- What kinds of experiences are planned to enable the teacher to learn about schools as an essential part of the community and national well-being?
- What evidence is there of the kind of relationships the teacher establishes with adults of occupation and interests different from his own?

A. **Relations with parents.** The teacher will demonstrate his understanding that good relations with parents can be an important asset in the development of an effective science program.

1. Describe the results of evaluation to parents so that it is clear whether the pupil is making reasonable progress in science.
2. Recognize the personal concern of a parent for his child, and show respect and appreciation for this concern.
3. Show patience when a parent values his child's welfare above that of the class as a whole.
4. Demonstrate respect for the opinion of parents.
5. Encourage parents to relate out-of-school science experiences in which their children are involved.

B. **Relations with the community.** The teacher will take into account the local community values and institutions as he works with his class and in his school, and will demonstrate an active interest in local community values and institutions.

1. Demonstrate a knowledge of the science resources of a community and the ability to capitalize on these resources to create a more effective teaching situation in science.

   A child's parent who is a scientist is invited to assist children with individual study projects.

   A visit to a conservation dam is planned.

2. Present science experiences which allow pupils to reexamine prejudged values and stereotypes.

3. Become aware of local values, including attitudes toward science and science education.
4. Demonstrate an active interest through participation in local community affairs.
5. Indicate through his actions an acceptance of the people of the community though he may disagree with some of their values and mores.

C. **The School as a democratic institution.** The teacher will demonstrate his knowledge of the school as a part of a community, and as an essential democratic institution in society.

1. Demonstrate pride in his school and his profession, and in the kinds of science experiences that children in his class are having.
2. Recognize the role of the school in community life.
3. Take an active interest in local, state, and national affairs that affect education and its support.

4

THE TEACHER AS A LIBERALLY EDUCATED PERSON

This Report would be incomplete without full recognition of the importance of liberal education in the preservice education of elementary teachers. All teachers must be liberally educated persons, and consideration of this requirement must be foremost in the development of teacher education programs. But the seven conferences were not structured to involve all of the many persons who must have a part in the planning and carrying out of liberal education programs. Because of this, no attempt has been made to provide guidelines for liberal education, even though this responsibility of teacher education institutions is clearly recognized.[19]

Liberal education is commonly defined by a prescribed number of courses in the humanities, social sciences, natural sciences, and the arts. Robert Bush describes it as "an education which liberates the mind from the shackles of prejudice and superstition and the confines of a single culture, that permits one to move freely and joyfully in the past and the present and to speculate objectively with his fellow men about the future." [20]

Such a definition admits that a liberal education is not achieved by the simple acquisition of a core of knowledge, however complete it may be. It must include an understanding of the interrelationships among ideas and people. It is an active pursuit which never ends.

Many activities other than formal courses can contribute to a liberal education. Colleges provide valuable informal experiences in the form of concerts, lectures, and plays; in some colleges, students attend these activities; in none are they a way to satisfy requirements for graduation. Is it not possible to encourage participation in these and other informal activities as a means of satisfying the need for a liberal education? Why not provide areas in dormitories or in student centers where students can paint, make pottery, and do wood or metal work? Off-campus experiences such as living or working in a ghetto area, visiting courtrooms or hospital emergency rooms, or working for agencies where the student would have close contact with segments of society with which he lacks familiarity could contribute to the student's education in a way that is impossible through formal study.

Far too little has been done to recognize the contribution that such activities can make toward the education of the liberal man. Procedures can and should be devised to include informal learning experiences in the liberal education program, to devise a means to assure that the experiences result in the learn-

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[19] See footnote 6, page 9.
[20] Robert N. Bush, "The Formative Years" in *The Real World of the Beginning Teacher*. Report of the 1965 Conference of the National Commission on Teacher Education and Professional Standards, National Education Association (1966) p. 4.

ing that was intended, and to recognize the contribution that is made to the degree program.

Informal experiences can help students relate ideas to the "real world" of people and social institutions and to associate the ideas from one field of study with those from another. But the organization of formal courses must also be considered. There is a place for interdisciplinary courses and a great deal more can be done in courses within a discipline to relate ideas to other fields. Certain lectures by sociologists could contribute to the course in biology, historians could contribute to the course in chemistry, anthropologists have something to say about ancient history, economists about urban culture. Such possibilities are limited only by the energy and imagination of the professor.

Appropriate science experiences can also contribute to the liberal education of teachers. However, as Arnold Arons points out[21] "little of . . . the intellectual component of the study of science has penetrated the text books and other course materials used in general education programs." It is not enough simply to teach students the results of scientific inquiry and to expect them to develop intellectual insights into the scientific process by themselves. To be liberally educated in science, teachers should learn that scientific concepts are created by acts of human intelligence and are not merely objects that are discovered. Arons suggests, for example, that it would contribute to the liberal education of a student if he were to understand that Galileo *intuitively* selected the concept of falling bodies, change of velocity with time, rather than the alternative, equally logical, but less elegant concept of change of velocity with distance. By means such as this students would "have the opportunity to examine what happened, to relive some of the intellectual experience, and to analyze and assess the line of thought, recognize its logic, its strengths and its limitations."[22]

Three questions must be considered by those who design experiences for teachers in the area of liberal education: How does one equip the teacher emotionally and intellectually for the uncertain world of the future? How does one develop the capacity and disposition for continuous learning? How does one develop a sensitivity toward and appreciation for individuals—including those individuals whose ideas are different from his own?

The acquisition of the behaviors described in the objectives of Chapters 2 and 3 will contribute to the goals implied by these questions and thus contribute to the liberal education program.

In this age of rapid social change, instant communication, and accelerated technological development, the need for better understanding among individuals from different cultural traditions is more important than ever before in history. Our society is troubled by individuals who question the values of our institutions and the effectiveness of our political systems. Society is confronted

[21] "Science; The Art of Inquiry," Arnold Arons, in *Change in Higher Education*, May-June 1969, pp. 31-35.
[22] Ibid, p. 33

by the fact that various ethnic groups have been deprived of opportunities that are taken for granted by others. The disparity between the material wealth of different nations is forcefully displayed by the mass media. All of these forces compel each individual to question his philosophical position and his obligation as a citizen of the world. Surely a liberal education should prepare teachers to face these and other social issues openly and with rational consideration.

Educators must face the fact that much of what we teach today will be obsolete or irrelevant in the near future. Perhaps the most important characteristic of the liberal man is his ability to keep informed and his willingness to adapt to changing conditions. We must educate for the future.

Experiences that prepare teachers for the future—that prepare them for continual self-renewal and rational adjustment to inevitable change—are an essential part of their preparation. Experiences in science and with children and schools contribute to the development of necessary attitudes and skills but they will not be sufficient. It will be necessary for many other groups to give serious consideration to this problem and to provide the needed guidelines and descriptions of behavior that characterize the liberal man.

5

RESEARCH AND DEVELOPMENT

Development Projects

Science Programs

College science courses should be developed which will accomplish the objectives outlined in Chapter 2 and which will provide a more appropriate model for teaching science to children. Several new promising science courses for college students who are not science majors have been prepared in recent years. However, performance specifications are not stated for these courses and little provision is made for individualized instruction. The relationship between what is taught in the courses and what is taught in schools is not always clear.

It is possible for each institution to develop its own science materials but the personnel and financial resources that would be required for the undertaking that is envisioned preclude this procedure. It is desirable that sets of materials be developed by a number of different groups so that the teacher education institutions will have several programs from which to choose. The programs should be developed cooperatively by specialists in science and specialists in education, including educational psychologists. The materials should be field tested and carefully evaluated before they are widely used. Some suggested characteristics of a science program for teachers are outlined below.

- **Objectives:** The science requirement for elementary teachers and the instructional materials that they would study would be based on performance objectives. With necessary elaboration and modification the objectives outlined in Guidelines I through V could provide the framework for these specifications.
- **Assessment:** Assessment devices which correspond to the performance objectives would be developed to evaluate quantitatively the effectiveness of the instructional materials. The quantitative results of performance assessments should be the major criteria in deciding on needed revision of the instructional materials.
- **Individualized instruction:**[23] The instruction would be individualized so that students can satisfy the requirements in different ways and in different lengths of time. In support of the individualized instruction, entry level tests (Does the student possess the prerequisites for the course?) and

[23] Both the Intermediate Science Curriculum Study (ISCS) at Florida State University and the Audio Tutorial program at Purdue University have characteristics of individualized instruction. Although neither of these provides an exact model for the materials that should be developed, each contains ideas that could be incorporated.

diagnostic tests (What competencies in the course does the student already possess?) should be designed. Students who demonstrate a particular competency before instruction would by-pass activities designed to develop that competency.

- **Inquiry:** The instructional materials in the proposed science program would emphasize the processes of science as well as science concepts. Process is used in a broad sense; emphasis should be on developing the skills of scientific inquiry rather than on accumulated knowledge.
- **Concepts:** A science course which emphasizes process should also teach science concepts. Concepts should be drawn from areas normally treated in the new elementary science courses.
- **Laboratory:** The course would be organized around the laboratory,[24] in the broadest sense of the word, including field work, and students should have opportunities to conduct investigations of their own design. Student progress should be checked frequently and remedial activities or alternative exercises prescribed when they are needed.
- **Integrated sequences:** The science experiences for elementary teachers would comprise an integrated sequence including physical, biological, and earth sciences. As a first step, major improvements could be made if separate materials in physical science, including earth science, and biological science were developed.
- **Relevance and interest:** Emphasis should be placed on the careful selection of science experiences that will be both relevant and enjoyable. Materials should be developed that treat problems related to the impact of science and technology on society and the environment. The limitations as well as the power of science should be considered.

Development of coures with these characteristics must respond to the reality of large enrollments and limited resources. Alternatives must be sought for effecting desired learning among large numbers of students by small numbers of qualified professors. A person of professional rank should have primary responsibility for the organization of each course, and he should be provided an adequate number of assistants to perform instructional, technical, and clerical functions. The professor must have direct contact with the students enrolled and the students must have ample opportunities to discuss scientific concepts with the staff and with each other. Furthermore it will not be enough to provide student materials alone. Written teacher's guides should be developed simultaneously with new course materials designed for students.

Conducting studies of science teaching practices. Assuming that the future science teaching practices of the elementary school teacher will be strongly influenced by the style of teaching in his college science courses, a number of

[24] Laboratory refers not to a room in a building or a section of a course, but to the concept of "hands on."

aspects of the college science program should be carefully considered. Some of these are:

1. Interaction patterns between professor and student and between student and student.
2. The climate of the learning environment.
3. Individualization of instruction.
4. Active participation of students in setting goals for their own learning.
5. Greater emphasis on laboratory investigations than on lectures.
6. Laboratory investigation rather than cookbook laboratory manuals.
7. Use of a variety of learning materials rather than a single textbook.
8. Attitude toward science and learning.

Education Programs

There is a need for new materials and new approaches in education as well as science. The USOE Model Projects provide ample suggestions for the development of these materials—their influence could be revolutionary. The focus of these programs is on preparation of the elementary teacher without specific reference to disciplines as such, but the framework of these Models and their philosophy have many implications for preparation to teach science. If professors of education with special interest and responsibility for preparation to teach science have participated in planning the science experiences, as it is strongly recommended that they be, then they will be in a better position to develop educational materials that supplement the science experiences making use of many ideas in the Model Projects.

Fresh approaches and new directions are needed in programs to provide experiences with children and schools. Specific behaviors desirable for teaching science to children should be identified first. It is then recommended that projects be implemented in which experiences planned to develop these behaviors are provided through modules of instruction, seminars, readings, research participation, or other structures without the limitations of credits and traditional courses.

Some characteristics of proposed development projects are the following:

- **Objectives:** The education requirement for elementary teachers and the instructional materials that they would study should be based on performance objectives which specify the behaviors desirable for teaching science to children. With necessary elaboration and modification the objectives outlined in this Report under Guidelines VI through IX could provide the framework for these specifications.
- **Assessment:** Assessment devices which correspond to the performance objectives must be developed to evaluate the effectiveness of the instructional materials. The quantitative results of performance assessment should be used to suggest modifications of the education program.

- **Individualized instruction:** It is recommended that much of the instruction be individualized so that students can satisfy the requirements in different ways and in different lengths of time. In support of the individualized instruction entry tests (Does the student possess the prerequisites needed for the course?) and diagnostic tests (What competencies in the course does the student already possess?) must be designed. Students who demonstrate a particular competency before instruction would bypass activities designed to develop that competency.
- **Service centers:** "Professional service centers" in teacher training institutions should be established where the students could obtain advice about problems they encounter in teaching without the threat that is often associated with taking problems to college supervisors or cooperating teachers. Such centers should have specialists in testing, in audio-visual materials, and in systemic design of teaching methods, and psychologists available for consultation by students.
- **Vicarious teaching experiences:** Filmed classroom episodes showing good science teaching, and associated study materials in which the prospective teacher identifies appropriate teaching strategies should be prepared.
- **Micro-teaching:** Simulation and micro-teaching materials designed especially for teaching science should be prepared. The materials should be arranged in sequence to progress from teaching one child, to two or three, to larger groups as preparation for teaching science in the usual class of thirty or more.
- **Practical experiences:** Organization of seminars on one or more of the new elementary programs including opportunities to teach units from these programs to children is recommended.
- **Independent investigations:** "Invitations to Inquiry," a collection of suggested investigations in science which could be done by teachers independently or in small groups outside formal class organizations, should be developed.
- **Action research:** Students and teachers should have responsibilities in research and development projects related to college and pre-college science education. The involvement itself could lead to greater understanding of and more positive attitudes toward learning and teaching science. It would provide a major personnel resource necessary to accomplish development and change in science education. Experiences in which teams of students and professors cooperate in the development and field trial of experimental units in science should be provided.

Cooperative Arrangements with Schools

Personnel in colleges who are responsible for the preparation of teachers need closer contact with changing programs in the schools. Models which provide for sharing the responsibility for teacher education between college and school personnel are needed. Such models should provide for joint financing of programs and for cooperative efforts in making decisions about the program. Provision should be made for classroom teachers to assume active roles in that part of the preservice program carried out in the college and for college professors to provide services during that part of the program carried out in the schools.[25]

If teachers are prepared by the preservice program to teach new elementary school science programs, personnel in schools must lend support and encouragement. Such support is often missing because school administrators and concerned parents do not understand the new science programs and resist the changes which are being encouraged. Structured procedures at the state and local level may also inhibit recognition and acceptance of new programs. Such resistance is real and important. Its causes must be understood and dealt with.[26]

There are several possibilities for projects aimed at educating the public and school officials as to the methods and purposes of new science programs. Conferences for administrators represent one; the inclusion of administrators in inservice programs for teachers is another. Still another suggestion is that an "elementary science sampler" including materials from several of the new elementary science curriculum projects be prepared to introduce laymen to the new programs. Filmed materials which show these materials being taught might be included to give an idea of ways modern science is taught to children.[27]

Research Projects

Science Programs

The effectiveness of college courses and programs is taken too much for granted. By demonstration we see exciting course outlines, we hear stimulating lectures, we observe interested students, and we know many excellent teachers who were graduated from these programs. To date very little has been done to measure how the college science experiences affect what the elementary school teacher does in the classroom and how effective he is in developing an attitude of scientific inquiry in his pupils. Effects of college courses and programs, while complicated by a multitude of difficult-to-control variables, should be studied by carefully designed research projects.

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[25] Programs developed at the University of Maryland and the University of New Mexico are representative of the kind of cooperation described here. Brief descriptions of these two programs may be found in *Teacher Education: Issues and Innovations*, the 1968 Yearbook of the American Association of Colleges for Teacher Education.

[26] For an excellent discussion of sources of resistance see: Watson, Goodwin, "Resistance to Change", Concepts for Social Change, pp. 10-25. Edited by Goodwin Watson. Washington, D.C.: National Training Laboratories, NEA (1967).

[27] Elementary Science Information Unit. Far West Laboratory of Educational Research and Development, Berkeley, California.

It is recommended that research emphasis and priority be assigned in the following areas:

1. To determine what the competencies of the elementary teacher of science should be. The Guidelines of this report may be considered to be testable hypotheses of desirable competencies.
2. To determine whether these competencies are being achieved in the teacher's preservice college science experiences.
3. To determine whether the pupils of the elementary teacher, who has achieved the competencies that have been identified, develop desirable competencies in science.

The importance of identification and control of variables in specific studies related to these three areas, cannot be overemphasized. The research will require real expertise and probably would best be undertaken by teams of researchers that include scientists, specialists in learning and elementary education, and statisticians with competence in research design.

The guidelines of this report indicate the variety of teacher outcomes which must be related to program characteristics. Other teacher outcomes that are important should also be examined. For example, a teacher's feelings about science and the values of teaching science in the elementary school appear to be crucial factors in effective elementary science teaching. Other important outcomes include the teacher's ability and willingness to relate science experiences in other subject fields. Work is needed to relate preservice science program characteristics to the outcomes indicated in the guidelines of this Report. Other desirable outcomes of the science program that might be the subject of research are how to develop the following attitudes and performances in teachers.

- That science is lively and interesting.
- That scientific inquiry can be carried on in elementary classrooms.
- That he can adequately deal with investigations even though he does not know the "right answer."
- That he can adequately deal with and learn new subject matter in science.
- That methods of teaching science can be transferred to the teaching of "nonscience" subjects.
- That science learnings and experiences are connected to social learnings and experiences.
- That science experiences are used as a vehicle for the development of skills in writing and artistic representation.

Several of the committees who studied the Preliminary Report suggested that research should be done on the personal characteristics and attitudes that are necessary to be an effective elementary school teacher, including those attitudes that are most desirable for a teacher of science. It was further suggested that such a study should start with the student entering college, continue through the pre-service years, and into the initial teaching experiences. In addition to research relating personal characteristics and attitudes for effective elementary school science teaching, research already done and in progress on the concerns of prospective teachers should be studied for possible use in research and program development.[28]

Programs With Children And Schools

In addition to the research projects suggested for the preservice science program, research in experiences with children and schools was also considered at the AAAS conferences. Some of the suggested projects were quite specific, others were broad. Among the specific proposals were the following.

- If the teacher is engaged in planning as well as carrying out investigations in his college science program, does he do a better job of teaching science modules to children than if his college science investigations had been planned for him?
- What kinds of classroom behavior will enable the teacher to increase class participation by more children, for example, does the length of time the teacher waits before asking another question or calling on another child increase class participation by slow children? [29]
- Will pupils acquire a particular behavior, such as the ability to construct a test of a hypothesis, faster if they are taught in large groups, small groups, or individually?

Other somewhat less sharply defined questions were raised concerning the effect of preservice experiences with children on the teacher's performance in the work situation.

- Will early contact with children make prospective teachers aware of problems of teaching science to children and in turn increase the value of their other college experiences?
- How well does the teacher's performance in micro-teaching and simulated classroom situations predict his later performance in the schools?

Other questions relate to the teacher's attitude toward science.

- To what extent can these attitudes be changed? How do these attitudes develop in the first place?
- Is it true, as some educators suggest, that inept teaching by graduate assistants results in the alienation toward science so frequently observed in elementary teachers? If so, would it be possible to prevent such alienation by providing graduate assistants with special training to teach?

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[28] See Frances F. Fuller, "Concerns of Teachers: A Development Conceptualization," *American Educational Research Journal*, Vol. 6, No. 2, March 1969, pp. 207-226; idem, "Intensive Individualization of Teacher Preparation in Mental Health and Teacher Education," 46th Yearbook of the Association of Student Teachers, 1967, pp. 151-187. Dubuque, Iowa: William C. Brown.

[29] This topic was suggested by work done by Mary Budd Rowe at Teachers College, Columbia University.

Two broad areas of needed research were identified: the cost effectiveness of different instructional procedures, and ways that needed changes in social institutions such as colleges and schools can be brought about.

Thorough study of the many questions pertaining to the preparation of elementary teachers will require decades, and improvements are needed now. We cannot wait for research to provide all of the useful measurements before we decide on our educational shoes. But just as shoes are replaced, so are educational practices. By continuing effort in both development and research, the improvements in preservice education of elementary teachers that are needed today can eventually be brought into being, some of them within a few years, if the effort and support is as massive as the need dictates.

6

INSTITUTIONAL STANDARDS

The purpose and primary force of this Report is to describe competencies that will enable elementary teachers to provide exciting and profitable science experiences for children. The competencies have been derived from nine guidelines stating what the elementary teacher should be able to do when he has completed a preservice program. The guidelines are applicable to planning, executing, and evaluating preservice science education programs for elementary teachers.

This chapter states five institutional standards that seem essential if the institution is to be able to achieve the broad goals set forth in the guidelines. These standards are guidelines to institutions in establishing a framework in which effective teacher education programs can function.

A Cooperative Enterprise

Responsibility for teacher education programs is properly placed on many individuals and groups associated with institutions of higher education; the schools, state departments of education, professional organizations, and the public served. Greater involvement of all of these individuals and groups is extremely important in all phases of teacher education from initial planning through evaluation, teacher placement, and follow-up after graduation. This broad involvement is also important for special parts of the teacher education program, including preservice science teacher education to which the standards are directed.[30]

Standard 1. The institution should make certain that science and elementary education departments share the responsibility for the preservice science education of elementary teachers and that in meeting this responsibility these departments cooperate fully with each other and with schools, state departments of education, and interested persons and agencies.

- What evidence is there of sharing of responsibility by scientists and teacher educators?
- What are the relationships of the institution with other agencies that can contribute to the preservice science education of elementary teachers?
- Do college staff members know what is going on in elementary school science classes, and do school personnel work with the college faculty in developing elementary teacher education programs?

[30] Questions follow each standard. These questions are included for use by those who will evaluate the programs.

Staff

The most critical factor in good teaching is the staff. In no segment of her education is excellence of teaching more important than that in the cher education program. The quality of planning for teacher education, unseling future teachers, leadership in both class and out-of-class science periences of prospective teachers, and the search for knowledge through search and development also depend upon staff competence. Some members the staff should have had experience in teaching elementary school science; d all of them should be knowledgeable about recent research and development projects related to elementary school science. Participation in such projects is an exceedingly valuable experience for one who teaches courses for eservice elementary school teachers.

Standard 2. The institution should insure that the science preparation elementary teachers is under the direction of a professional staff which a) exhibits competencies in science; (b) is knowledgeable about elementary school methods and programs; and (c) works cooperatively with olleagues in other departments.

- What evidence is provided that those individuals who teach science to elementary teachers are competent in the science that they teach?
- What evidence is provided that those individuals who teach science to elementary teachers are familiar with materials and techniques used to teach science in elementary schools?
- What evidence exists that those individuals responsible for the science preparation of elementary teachers are provided necessary time and material resources to develop courses and programs deemed appropriate for elementary teachers?

Curriculum

Next in importance to staff is the curriculum for the preservice science education of elementary teachers. The nine guidelines provide the framework upon which the curriculum of science and science teaching experiences can be based. Curriculum as used here refers to all experiences that the institution provides to assist the prospective teacher in acquiring competencies needed for teaching science to children.

Standard 3. The institution should structure a curriculum designed to: (a) provide a full liberal education for the future teacher, including a strong science component; (b) prepare the student for life as a useful citizen and responsible leader in a society whose every aspect is conditioned by science; (c) enable the student to become a proficient and knowledgeable teacher of science and other subjects that he will be called upon to teach; and (d) enable the student to be confident of his professional role as a science teacher, and of the importance of what he does for society.

- Which parts of the curriculum contribute most to the teacher's liberal education?
- What evidence is there that the teacher will become a useful citizen and responsible leader?
- What kinds of evidence are available that the student is a proficient and knowledgeable teacher of science?
- How does the institution judge the degree of confidence in the importance of teaching on the part of the preservice teacher?

Individualizing Instruction

In this report, individualizing instruction means that the past experience and the learning rate of each student are considered when instruction is planned. It means that experiences are assigned on an individual basis. It does not mean that a single person is the learning audience; some instruction may be done better in groups and some may be done better with individuals. The most efficient organization for a particular type of learning is still a matter for research. It is the belief that instruction can be made more efficient and meaningful when students are considered individually that led to Standard 4.

Standard 4. Institutions which prepare teachers should make every effort to allow for individual differences among students by planning instruction so that students may progress at diffierent rates and by giving credit in completing program requirements for learning that is acquired before entering college or that is acquired through informal experiences during college.

- What procedures are used to determine those competencies that students possess in a given field at the time they begin the appropriate college courses?
- What procedures are used whereby students may bypass instructional segments designed to teach what they have previously demonstrated they can do?
- What evidence is provided that students may have a choice in determining how they will acquire a given competency?

Facilities and Materials

Throughout this report the emphasis is on the competencies that elementary teachers should exhibit. There is no intent to describe the equipment, the written materials, or the laboratory facilities that colleges and universities should have to conduct a teacher education program. Still, it is not uncommon for elementary teachers to take all of their science courses without laboratory experience. Many elementary teachers are graduated without an opportunity to see equipment and materials designed for teaching science to elementary school children. Libraries that they use have few books that may be used for reference when planning science experiences for children.

Standard 5 makes explicit the desire for proper facilities for the teaching of science to teachers. It pertains to conditions that should be provided by the teacher preparation institution.

Standard 5. The institution should (a) provide laboratory facilities which will accommodate student activities that range from predetermined exercises proposed by the professor to student-constructed experiments; (b) furnish science equipment and materials similar to those in elementary schools; and (c) provide reference books suitable for use in a school setting.

- What facilities are provided for teachers to conduct laboratory activities?
- What kinds of equipment, materials, and books are provided which enable teachers to prepare to teach science in elementary schools?

7

STRATEGIES FOR IMPLEMENTATION

Participants in the four conferences held in October and November, 1969, made many suggestions for implementation of this report. They further recommended that these suggestions be referred to special groups for initiation. A number of recommendations were addressed to AAAS and the Commission on Science Education. The Commission will make a major effort to respond, but change can be effected only with the cooperation of the National Association of State Directors of Teacher Education and Certification and many other individuals and groups. The conference recommendations for implementation follow. Your assistance is solicited in carrying out those of the recommendations appropriate for your situation.

Colleges and Universities Preparing Teachers

1. Assume responsibility through cooperation of departments of science and education for establishing competencies for elementary teachers consistent with these Guidelines; accept responsibility for the development of these competencies, recognizing that competencies can be developed in courses and in many other ways through appropriate experiences; accept responsibility for developing procedures for evaluating the success of students in achieving these competencies.
2. Advise students planning to teach in elementary schools early in their college career about the competencies needed in teaching elementary school science, and describe experiences that will help them develop these competencies.
3. Seek teachers with the specified competencies to act as cooperating teachers.
4. Make one person on each campus responsible for stimulating and coordinating the implementation of these guidelines.
5. Conduct discussion sessions among college faculties and students, recent graduates, elementary school teachers, district administrators and supervisors. Every opportunity should be taken to generate formal and informal discussions of the Report.
6. Consider the Report in the perspective of its significance as being prepared by a national project jointly sponsored by AAAS and NASDTEC and involving 500 participants in seven conferences.
7. Maintain an internal structure developed for study of this Report for continuing dialogue and consultation among scientists, teacher educators, and the schools.

8. Plan seminars to demonstrate the new elementary school science programs as background for discussion and implementation of the Report.
9. Prepare reports describing how these guidelines and recommendations are being used in your college for presentation at professional meetings and for publication in professional journals.
10. Provide for review of the Report by disciplines other than science for possible application in these disciplines and support in developing the competencies.
11. Encourage teachers of science education courses to use teaching strategies that they want elementary teachers to use.
12. Plan research and development projects so that faculties become actively involved in finding answers to questions related to the preservice science education of elementary teachers.
13. Plan preparation programs for paraprofessionals who will be able to make it more feasible for schools to offer effective modern elementary school science programs.

State and Regional Action

These recommendations are phrased for state action but they apply equally well for regional action, involving a part of a state or several states.

1. Conduct state-wide meetings of scientists, teacher educators, state department personnel, school administrators, teachers, and lay leaders for discussion of the Report and ways of using it.
2. Identify an individual in each state who will be responsible for dissemination of these guidelines and encouragement for their implementation; and to establish communication with state professional associations. He should be assisted by a state committee.
3. Solicit names of potential leaders for state consideration of guidelines and other leadership roles from such groups as the Council of State Science Supervisors, Council of State Elementary Consultants, Academy of Science, State Science Teachers Association, and TEPS Commission.
4. Request state school administrators associations, school board associations, and PTA's to provide for presentation and discussion of the Report at their regularly scheduled meetings.
5. Assist state education departments in carrying out their role of stimulating improvement and innovation in teacher education.
6. Inform industry and the lay public about modern programs in elementary school science and in needed improvements in teacher education.

7. Submit reviews of the Report and ways in which it has been used for publication in state journals.

8. Generate pressure from boards of education and administrators to require that beginning teachers be prepared in compliance with the guidelines.

State Academies of Science

9. Consider the report and determine appropriate steps for implementation, including: (a) endorsement by the group; (b) offering assistance to teacher education institutions and to the state education agency; and (c) further development of performance objectives in science and in education.

State Education Agencies

10. Appoint a planning committee to promote widespread introduction and discussion of the Report.

11. Conduct a state conference on science education for elementary school teachers, utilizing the Report. Conference goals should be to provide opportunity for dialogue among the communities of sciences, science education, and elementary education, and to develop action programs within the state, including models for operation.

12. Compare the report with state regulations for any possible conflicts and consequent needed changes in the state standards.

13. Present the report to the state's Professional Education Standards Board for possible adoption or approval.

14. Use the standards and guidelines in evaluation of teacher education program approval and/or state accreditation.

15. Serve as clearinghouse for developments within the state and in other states and communicate periodically to interested groups within the state.

16. Maintain relations with AAAS and NASDTEC in order to promote effective use of the standards and guidelines.

Professional Organizations

The assistance of national and state professional organizations in science and mathematics should be sought to:

1. Distribute copies of the Report to their members who can make use of it.
2. Provide for presentation and discussion of the Report at one or more regular meetings.

3. Sponsor special conferences for introduction and discussion of the Report.
4. Publicize the Report and uses of it in their journals.
5. Develop outlines of materials to assist colleges in providing appropriate preservice science teacher education experiences, and evaluation instruments for determining when prospective teachers possess the desired competencies.

Appendices

Not all of the suggestions and recommendations of the committees have been incorporated into the body of the report. Some of these ideas are included in Appendix B under the headings Gems (short statements about desired activities and outcomes), Science Experiences, Experiences with Children and Schools, Liberal Education, Implementation and Research. Those who read and use this report may find many of these suggestions helpful.

To keep Chapter 2 from becoming unwieldy, the performance objectives for Scientific Knowledge were stated in general terms rather than in detail. However, it was felt that this treatment of the objectives would not be as helpful as more specific statements to those developing new science programs. To assist developers of new programs to prepare their own specific objectives, an example of more detailed objectives is given in Appendix C for the topic The Composition, Characteristics, and Structure of Matter.

Appendix A

GUIDELINES AND STANDARDS

Guidelines

Guideline I. Science for elementary teachers should be taught in the same style of open inquiry that is encouraged in elementary science programs. The student's science experiences should develop his ability to actively investigate natural phenomena and should result in his enthusiasm for and confidence in teaching science through inquiry to children.

Guideline II. Science experiences of elementary teachers should develop in teachers an appreciation for the historical, philosophical, and current significance of science to society, and positive attitudes about science which result in a more objective approach to everyday problems, in improved teaching of science in their classroom as well as in increased interest in science-related activities.

Guideline III. The science experiences for elementary teachers should develop competence in inquiry skills or processes of scientific inquiry.

Guideline IV. The content of college science experiences for elementary teachers should be selected so that the topics studied by teachers provide, as a minimum, an adequate background for the topics taught in elementary schools.

Guideline V. Science experiences should be selected so as to develop a capacity and disposition for continuous learning which the teacher should demonstrate by engaging in science activities which will provide new information and experiences capable of affecting existing attitudes, ideas, and teaching.

Guideline VI. The institution, working cooperatively with schools, should provide experiences with children and schools so designed that the teacher develops the skills required for effective instruction in the science program.

Guideline VII. The institution should insure that the teacher possesses skills required for effective human relations with children in the classroom by carefully and continually screening candidates for the teacher education program and providing experiences in which students develop the desired behaviors.

Guideline VIII. The institution should provide experiences which will enable the teacher to develop cooperative working relationships with other teachers and administrators of the school faculty which he joins and to work effectively in a variety of organizational patterns for science instruction.

Guideline IX. Experiences in schools and in a community should be provided to develop a sensitivity toward, and an appreciation for, the school as a part of the community and as a democratic institution, and for individuals in the community.

Standards

Standard 1. The institution should make certain that science and elementary education departments share the responsibility for the preservice science education of elementary teachers and that in meeting this responsibility these departments cooperate fully with each other and with schools, state departments of education, and interested persons and agencies.

Standard 2. The institution should insure that the science preparation of elementary teachers is under the direction of a professional staff which (a) exhibits competence in science; (b) is knowledgeable about elementary school methods and programs; and (c) works cooperatively with colleagues in other departments.

Standard 3. The institution should structure a curriculum designed to: (a) provide a full liberal education for the future teacher, including a strong science component; (b) prepare the student for life as a useful citizen and responsible leader in a society whose every aspect is conditioned by science; (c) enable the student to become a proficient and knowledgeable teacher of science, and other subjects that he will be called upon to teach; and (d) enable the student to be confident of his professional role as a science teacher, and of the importance of what he does for society.

Standard 4. Institutions which prepare teachers should make every effort to allow for individual differences among students by planning instruction so that students may progress at different rates and by giving credit in completing program requirements for learning that is acquired before entering college or that is acquired through informal experiences during college.

Standard 5. The institution should (a) provide laboratory facilities which will accommodate student activities that range from predetermined exercises proposed by the professor to student-constructed experiments; (b) furnish science equipment and materials similar to those in elementary schools; and (c) provide reference books suitable for use in a school setting.

Appendix B

ADDITIONAL ITEMS FROM THE CONFERENCE REPORTS

1. Gems.

- The development of a science preassessment instrument for elementary education majors is needed.
- The teacher education program must be extended beyond four years.

- Use of paraprofessionals in elementary school science programs should be encouraged.
- The Report should also be addressed to junior college teachers since many prospective elementary teachers fulfill their science requirement in junior college.
- Colleges should provide outdoor laboratory facilities which will facilitate student activities focussing on environmental science.
- School system personnel should be directly involved in every phase of the development of the preservice science education of elementary school teachers.
- Experiences with school children should be provided during each undergraduate school year.
- Professional societies should develop positive attitudes among science professors in fostering interdisciplinary cooperation with science educators in development of the preservice science education of elementary school teachers.

2. Science Experiences

The recommendation that courses in science be taught closer to time of application (not in just the first two years of college) presents real problems since a potential elementary teacher may not emerge until granting of the B.A. degree. Consideration should be given to establishing seminar courses in education running in collaboration with basic science courses where relevancy and application of the principles to the elementary classroom will be explored. It might also be possible to run an interdisciplinary course at the upper division level in which representatives from the various scientific disciplines present to student teachers an overview of the concepts they consider fundamental to their field. Such presentations would then be followed by a presentation by the teacher primarily interested in methods. This person might give consideration to such topics as an overview of units, teaching aids and techniques appropriate to presentation of these concepts at the elementary level.

* * *

There is need for an additional specific guideline that would cover the social and humanistic relationships of science as they apply to such areas as: the use and management of natural resources, pollution, technology, population control, history of science, philosophy of science, and aesthetic values.

3. Experiences with Children and Schools

Prospective teachers are often not identified early enough to provide educational experience prior to formal education courses. Programs which begin as early as the freshman year should be tried. These programs might provide observational or tutorial experiences in science with children in schools. Through such experiences, prospective teachers could better decide whether or not education was the direction to take as a career and the institution could better evaluate the quality of the individual as to acceptance or rejection into the credential program.

* * *

It should be recognized that it may not be possible to develop the desired competencies in science during the traditional preservice education of elementary teachers. Moreover, until the teacher has been exposed to the classroom he cannot fully appreciate the problems of teaching science. The first few years are most critical in this respect. Every school system should establish a cooperative arrangement with a local college or university to provide continuing supervision and training in science in all elementary teachers during their first two or three years of service.

* * *

It is recommended that provision be made for field experiences in more than one type of school, at more than one level, and in more than one type of community, so that the students are given additional frames of references from which to make comparisons and future educational decisions. It is suggested further that similar provision be made for developing differentiated roles of teachers. This might be reflected in the report by indicating several alternative sequences of experiences that might be followed.

4. Liberal Education

Science being a human endeavor, the teacher as a liberally educated person should seek to be continually aware of the moral responsibilities for the use of science and should seek to keep students aware of these social issues. The scientific enterprise should provide resources for actively reducing racism, increasing respect for the individual and promoting the proper use of the environment. The report should reflect this more strongly.

5. Implementation

The impact of the student demand for change in styles of teaching and content currently being felt throughout the nation in colleges and universities is also affecting teacher training in those institutions. It seems highly opportune, therefore, that the teacher accreditation associations be contacted in the several states and regions as well as nationally, by AAAS in the interest of the new program in preservice education of science teachers.

We suggest that a most helpful first step would be the preparation, by AAAS in cooperation with accreditation and certification agencies, of criteria, which would be derived from the Guidelines, that would be used by accreditation teams in making helpful suggestions to colleges and universities for future development of their educational programs, most particularly those in preservice science education.

* * *

Accrediting and certification agencies should be encouraged to enforce restructuring of college curricula in accordance with the guidelines.

* * *

Institutions should encourage their science and science education faculties to establish working arrangements that promote mutual cooperation. These might include joint or adjunct appointments across departments, or the establishment of jointly staffed science teaching center or institutes.

* * *

One possible channel for dissemination is via institutes and workshops. In this connection there are two avenues which should be explored. The first would be the establishment of institutes and workshops which will work specifically on the development of science materials and experiences which are appropriate at the college level and which are compatible with the common features of the several elementary programs. The second would be to "infiltrate" institutes which are primarily designed for other purposes but which could logically and naturally contain a component on elementary science.

To catalyze the development of special institutes and to encourage the incorporation of the ideas in developing these Guidelines in existing institutes, a series of workshops *for institute directors and potential directors* should be sponsored. It appears that in this connection there is urgent need for models in which the very philosophy which is being advocated is used by the advocators. It is not our suggestion that the workshop participants go through the specific elementary materials as such but that utmost care should be exercised to see that the workshops do not violate the educational tenets which they advocate.

6. Research

A representative study might examine how the use of "open hours" in teachers' laboratory work (rather than fixed times) was related to

a. Teachers' beliefs that science is not a "foreign" special activity.
b. Teachers' beliefs about the importance of inquiry in science.
c. Teachers' responsiveness to individual differences in pupils (especially abandonment of "lock step" teaching).

In addition to the studies suggested by the elements of this report, research is needed to follow teachers completing programs for a number of years in their careers, to assess the effects on classroom performance of personality factors, and to suggest program characteristics that might be made dependent on the teacher's personality. How much the science program for prospective teachers should differ from the program for other nonscience majors seems dependent on the differences that may exist between these groups. How different are these groups in competence at the beginning, in expectations, etc.? What emphasis in the science courses and the methods courses will produce the greatest desired change in prospective teachers?

Although this report focuses principally on the connections between program characteristics and teacher outcomes, other forms of research are very relevant. For example, information concerning the techniques, devices, and approaches most effective in changing collegiate programs is needed. Knowing what an effective program would be and arranging for its operation are not the same. Individuals of good will need all the assistance they can receive in making their efforts effective.

Common sense and experience indicate that the program elements recommended in these guidelines should produce positive effects. But careful research tracing out the effects of these and related program elements is needed. *Where controlled research is not possible we can, at least, describe the consequences of our efforts at development.*

Not enough trustworthy information is available on the sequence:

Characteristics of collegiate	→	Teachers' competencies,	→	Teachers' actions in
programs.	←	beliefs, feelings in science.	←	teaching science.

The standards and recommendations of this report specify and suggest characteristics of collegiate programs that should be investigated. For example, some of the variables that might be manipulated are:

a. The number of teacher-designed laboratories in the collegiate program.
b. The extent to which simple materials are used in the collegiate laboratory.
c. The use of "open hours" in collegiate laboratory work (rather than fixed times).
d. The number of laboratory activities that have no predetermined "right answer" in the collegiate laboratory.
e. The teacher's freedom to take all his science in one field rather than requiring "distribution."

f. The assignment of collegiate learning experiences after pretesting rather than reliance on a "standard" program.

g. The number and variety of direct experiences with children in the first two years of the collegiate program.

h. The nature of the sequence of involvement in the teaching role (after example, going from tutorials to microteaching to involvement with large groups).

i. The nature of the internship (for example, the arrangements for supervision, the age of the pupils taught).

j. The degree to which decisions affecting the internship program are made by the cooperating schools.

* * *

One of the impediments to change is the lack of appropriate "ideas" or "models" to be used in the science preparation of elementary teachers.

The most commonly suggested solution to this problem is the production, field trial, and evaluation of curriculum materials for college students in the same way that materials have been prepared for use at the elementary and secondary level. Perhaps there is another step that could be undertaken now at less cost and with more immediate impact.

Consideration should be given to the establishment of a clearinghouse for instructional units or activities. Individuals would be encouraged to submit descriptions of their ideas to the clearinghouse. Those who did so would be rewarded by receiving a description of other ideas dealing with the same curriculum problem. An example may help:

Suppose that I have developed an activity (perhaps an A-T lesson, a programmed sequence or just a simple assignment) that I feel is particularly effective in getting teachers to "distinguish between acceptable and unacceptable responses to assessment items in science." I would write up the activity and submit it to the "clearinghouse" for inclusion there. My report would automatically be accepted providing the following criteria were met:

a. The objective of the activity is clearly stated.

b. The activity is described in sufficient detail that another teacher could replicate it.

c. The student population that was taught is described in brief (e.g., year in school, prior hours of science and professional education).

d. The "test" of the objective is included.

e. Student performance on the test is given (e.g., 80/120 students met criterion).

After my "activity report" was accepted, I would automatically receive copies of all other related activities in the clearinghouse bank—i.e., all activities dealing with assessment in science.

Perhaps one of the most important side effects of this project would be the identification of individuals in the country who are creative enough to make some original contributions. These people are the ones who should be participating in curriculum projects.

* * *

There is a need to provide students at all levels with the opportunity to be actively involved in research. One way to create this opportunity is to develop large-scale research projects each of which contains a multitude of sub-problems deserving of investigation. Undergraduates, involved in such research, would be better prepared to conduct research projects concerning their teaching. Further they might be more inclined to participate in or assist in research conducted in their school by outsiders. Students beginning work for a master's degree or doctor's degree could gain experience prior to the time they begin a thesis or dissertation. Finally, theses and dissertations which grow out of a central project will probably have the same theoretical basis. The result would be an increased amount of related research and fewer studies on problems which have little relation to one another.

Research activities should not be reduced to attempts at justifying new teaching practices. Rather they should try to answer questions raised by the systematic design of teaching methods.

Samples of research questions are:

- To what degree, and for what kind of performance category, can vicarious experience supplant hands-on experience?
- What are the conditions necessary and sufficient to instill the attitudes which result in improved science teaching in the classroom, a more scientific approach to questions in daily life, an increased interest in science-related activities?

Appendix C

PERFORMANCE OBJECTIVES FOR "THE COMPOSITION, CHARACTERISTICS, AND STRUCTURE OF MATTER"

The position taken in this report has been that institutions of higher learning can and should develop careful descriptions of what elementary teachers should be able to do upon completion of their college science program. These descriptions should be realistic in terms of the time a teacher has to devote to the study of science and they should take into account what teachers might reasonably be expected to teach to children.

Chapter 2 suggests broad topics that the group responsible for this report considered to be important for elementary teachers. It does not include the detailed specifications that would be a useful guide to those who are teaching science to teachers and who are concerned with improving their science programs. To include such detailed specifications would have made the report too unwieldy. However, to illustrate the kind of detailed specifications that should be prepared before attempting to change science programs for teachers, this appendix provides an elaboration of one topic, The Composition, Characteristics and Structure of Matter (see page 18).

Two things were considered in developing this elaboration of the material in Chapter 2; (1) What are the concepts under this general heading that are likely to be taught in elementary schools? (2) What should be the depth of the teacher's understanding of these concepts in order to do a respectable job of teaching science in elementary schools?

An examination of elementary science materials will show that most include a number of activities aimed at developing an understanding of matter. The SCIS unit *Material Objects* provides an excellent example of how elementary children might be expected to examine matter in terms of characteristic properties and to use these characteristic properties to identify, classify or order materials in a systematic fashion; ESS units such as *Gases and "Airs," Kitchen Physics,* and *Mystery Powders* provide similar opportunities; in many exercises in *Science-A Process Approach* children investigate physical and chemical properties of gases, liquids and solids; Volume II of the *Intermediate Science Curriculum Study* materials (designed for grade 8) is devoted to the development of a simple model for matter and most conventional elementary science texts discuss matter in terms of atoms and molecules. None of these presentations presume a detailed or sophisticated atomic theory and the major emphasis is placed on properties of matter and its interactions rather than theoretical statements or elaborate models. It seems reasonable that there should be a similar emphasis in the preparation of elementary teachers. The following objectives are written from this point of view.

What is the nature of matter?

I. Perform demonstrations that suggest that matter is composed of particles.

a) Demonstrate diffusion in liquids and gases and describe the observations in terms of a particulate model for matter.

b) Demonstrate that many forms of matter can be broken down into constituent parts and describe this decomposition in terms of a particulate model for matter.

c) Demonstrate the interaction of two forms of matter to form a new substance and describe this interaction in terms of a particulate model for matter.

d) Perform a demonstration to show that particles of matter are very small.

II. Perform demonstrations that suggest that the particles of matter are in constant motion.

a) Demonstrate diffusion in liquids and gases and describe the observations in terms of the motion of particles.

b) Demonstrate Brownian motion.

III. Provide evidence for the electrical nature of matter.

a) Place an electrical charge on an object and discuss common examples of static electricity in terms of the balance of electrical charge on matter.

b) Demonstrate electrical conductivity in solids and liquids and discuss conductivity in terms of the flow of electrical charge through matter.

c) Demonstrate the movement of colored ions under the influence of an electrical potential and name the charge on the ions.

IV. Use simple physical models to describe chemical changes in matter.

a) Use fasteners and rings, nuts and bolts, balls and sticks or other physical models to illustrate the combination of elements to form compounds.

b) Use chemical symbols to write formulas for simple compounds.

c) Write chemical equations to represent simple chemical changes.

How can different forms of matter be identified?

I. Name and measure (or describe quantitatively) at least six properties of matter that may be used to identify it.

a) Given samples of pure substances, some of which are solids, some liquids and some gases, measure one or more of the following properties and use the resulting data to separate the objects into sets such that all elements of a set have identical properties. The properties to be observed are: color, hardness, fracture pattern (what happens when you hit it with a hammer), density, melting point, boiling point, heat capacity, electrical conductivity, solubility in various solvents, and behavior on heating.

II. Describe evidence that may be used to distinguish between elements, mixtures and compounds and use that evidence to make such distinctions for simple cases.

a) Given homogeneous samples of solid materials, identify the materials as either mixtures, elements or compounds. Only samples which can be identified with relative ease should be used. For example, only elements that will not react upon heating in air; only compounds that may easily be decomposed by heat or electrolysis; only mixtures which do not have a well defined melting point or which consist of substances with gross differences in solubility in common solvents such as water and ethanol.

How is matter changed from one form to another?

I. Describe changes from solid to liquid to gas in terms of the arrangement of particles in the various forms of matter, the motion of the particles in each form, and the kinetic energy of the particles.

a) Heat water from -10 degrees Celcius to 100 degrees Celcius in an open container and describe the changes in terms of a particulate model for matter.

b) Measure the energy required to convert 10 grams of ice to water and 10 grams of water to steam. Describe the energy changes in terms of molecular motion.

c) Describe in qualitative terms the effect of temperature and pressure on the volume of a gas; a liquid; a solid.

II. Describe common chemical changes in terms of a particulate model for matter. Demonstrate at least five such chemical changes.

a) Describe rusting and other common examples of corrosion in terms of a reaction between the metal and oxygen. Prepare demonstrations to show the importance of oxygen in corrosion.

b) Demonstrate the reaction of an acid with a base.

c) Demonstrate the reaction of acids with carbonates. Describe the formation of caves, the cleaning of toilet bowls, or the action of baking powder in terms of this reaction.

d) Demonstrate decomposition upon heating as an example of chemical change.

e) Describe combustion in terms of the chemical reaction taking place.

What affects the speed and extent to which matter changes?

I. Demonstrate the effect of concentration, temperature and physical state on the rate at which changes in matter occur.

a) Demonstrate the effect of temperature on the rate of common chemical changes such as souring of milk and oxidation (burning) of paper.

b) Demonstrate the effect of concentration of reactants on the rate of common changes such as burning, acids reacting with metals, or bases reacting with fats.

c) Demonstrate the effect of physical changes such as pulverizing or dissolving on the rate of common reactions.

II. Describe factors that affect equilibrium in chemical and physical systems and demonstrate systems in equilibrium.

a) Describe differences over a period of time in a system consisting of water in a closed container and water in an open container and explain the differences.

b) Describe macroscopic and microsopic changes that occur in a saturated solution over a period of time and induce changes in the amount of solid material in the system by altering the system in one or more ways.

c) Demonstrate a system in chemical equilibrium and affect the system in such a way that macroscopic changes in composition can be observed.

How can matter be separated?

I. Demonstrate the separation of solids from liquids, solids from solids, liquids from liquids, using physical techniques such as filtering, centrifugation, sedimentation, distillation, and paper chromatography.

II. Demonstrate the separation of materials that are chemically combined through electrolysis, decomposition by heat, and displacement of an element by another element.

Some will undoubtedly argue that the above represents too much; that elementary teachers—particularly in the primary grades—can do an adequate job without benefit of many of the competencies described. Others will argue that it is far too little; that it represents no more than would be covered in a high school course in physical science; that any respectable college science course should go well beyond the level outlined here. There is truth in both positions. It is certainly true that the above is no more than might be covered in a high school course—indeed it is *less* than might be covered in a modern high school chemistry course. However, any person who has worked closely with elementary teachers can certainly testify that it describes a number of competencies that teachers do not possess even *after* they have had as many as 12-15 hours of "college level" science. There is considerabl evidence that in our rush to develop sophisticated ideas that are important and meaningful to professional scientists, we leave many of our nonscience-oriented students confused about these simpler, yet basic, ideas. In the judgment of this writer, the competencies described above will enable the elementary teacher to do a respectable job of teaching science in the area outlined. Further, it represents a level of understanding that should be attainable for all of the science topics described in Chapter 2 in a reasonable length of time. If additional time is available, more may be done but the above outline represents a minimum level of competence that can and should be attained by all elementary teachers.

—J. Dudley Herron

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Organizations

Dasbach
Jozwiak
Kabisch
Kormondy
Livermore
Mayor
Meyer
Overly
Rezabek
Smith, Mark
Wolfle

School Curriculum Project

Allen, L. R.
Bakke
Brown, R.
Burkman
Fishleder
Hacker
Humphreys
Karplus
Lipson
Livermore
Mayor
Shamos
Sheehan
Thier
Watson
Webb

NSF, Office of Education, Industry, Educational Laboratories

Binder
Blackwood
Boggan
Borg
Cason
Daen
Dickman
Edmunds
Foster
Howland
Hutchins
Lipson
McGuire
Phillips
Ritz
Steffensen
Steele
Wallace

Student

Knapp
Smith, B.
Young, G. M.